

Integrating the Cyber World with the Internet of Things: How to transform cities and industries into smarter places

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University of Messina

CINI

SmartMe.IO srl



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- Director of the CINI Italian Lab on Smart cities and communities <https://www.consorzio-cini.it>
- Responsible of the SmartME crowdfunding initiative to exploit Messina into a Smart city (smartme.unime.it)
- Co-founder of SmartMe (smartme.io)





Università
degli Studi di
Messina

DIPARTIMENTO DI INGEGNERIA



- Cloud computing
- Internet of Things
- Sensors
- Edge computing
- AI at the edge

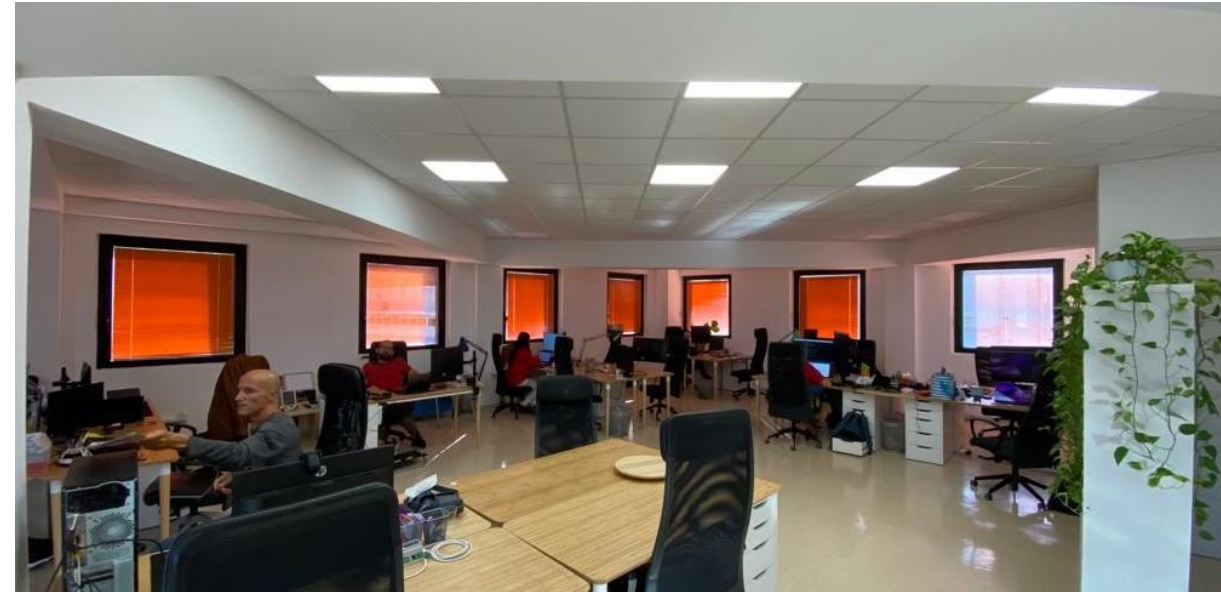
A consortium of 47 Italian Universities that:

- do research in CS/CE
- deliver BS, MS, PhD degrees
- are public funded
- Involves 1,300+ professors of CS or CE



Goals

- Pave the way to promote and stimulate **projects of national dimension**
- Develop a reference platform to manage smart cities with an *open* approach for software, data and hardware
- Create **Living Labs** to facilitate the development of new services for the citizens and strength the cooperation with PA and industries
- Adopt **re-using**, i.e. exchanging experiences and solutions among co-operating living labs



- Hardware design and production
- Firmware development
- Cloud/IoT integration
- Stack4Things maintainer
- SMART Cities, Industries, Agriculture



OUR PILLARS



OPEN SOURCE

We are doomed to know everything. The urgency is the sharing, sharing also of the good work, of free time ... **Henri Antoine Groués**



OPEN HARDWARE

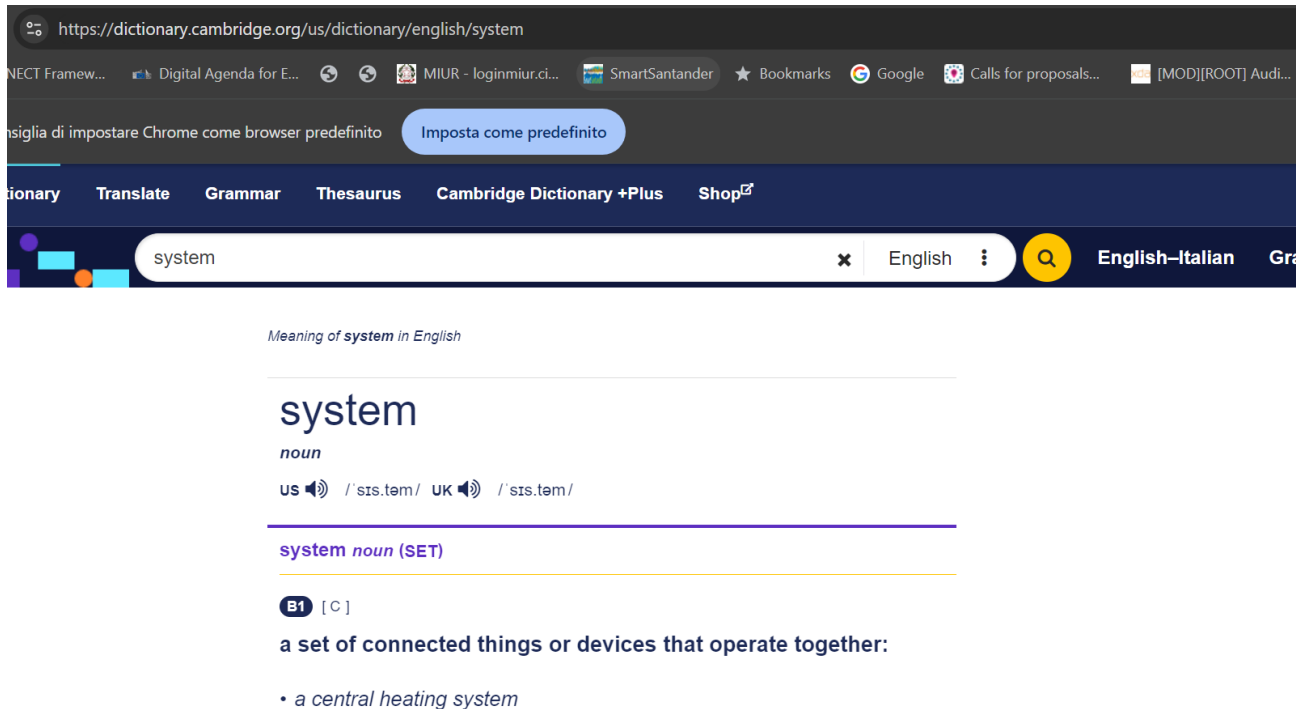
There is true sharing only in poverty. There is real wealth only in sharing. **Roger Etchegaray**



OWN YOUR DATA BY DESIGN

Nothing seems to me to have the least value, except what we get from ourselves. **Oscar Wilde**

CLASSICAL APPROACH



The screenshot shows a web browser with the Cambridge Dictionary URL. The search bar contains the word 'system'. Below the search bar, the definition of 'system' is displayed. It is a noun with the pronunciation /'sɪs.təm/ for both US and UK. The definition is 'a set of connected things or devices that operate together'. An example is given: 'a central heating system'.

https://dictionary.cambridge.org/us/dictionary/english/system

Meaning of **system** in English

system
noun
US  /'sɪs.təm/ UK  /'sɪs.təm/

system *noun* (SET)

B1 [C]

a set of connected things or devices that operate together:

- a central heating system

The traditional approach to the design and implementation of a system, whatever it is, focuses on the **strictly functional** aspects. The issues relating to what is "external" to the system or relating to "how" the system is created or its state during operation, are relegated to the application of shared standards or procedures such as:

- General legislation, environmental impact, rules relating to the impact on health, etc .;
- Quality assurance, product certification, sizing standards, etc ..

THIS APPROACH IS QUITE
LIMITED, NOR RESILIENT,
NEITHER PROACTIVE

SOME EXAMPLES IN DIFFERENT SECTORS



INFRASTRUCTURES

The project ends with the testing phase.



POLICY

The focus is on the objectives (costs) without considering the *health* of the system



INDUSTRIAL SITES

The focus is on internal objectives, forgetting the external world

NEURO-BIOLOGIC APPROACH

CONSIDERS ALL THE
IMPLICATIONS

REACT TO CRITICAL SITUATIONS

COMPARES RISKS AND
OPPORTUNITIES

INTRODUCES
PROACTIVITY

IMAGINES ALTERNATIVE
STRATEGIES

CONTINUOUS INTEACTION
WITH THE ENVIRONMENT



AUTO CONSCIOUS ARCHITECTURE

Inspired by neuro-biologic systems

LEFT HEMISPHERE

Serial Processor. Think linearly and methodically. Totally focused on the past and the future. Identify the details in the set of information provided by the right hemisphere, then categorizes, organizes, associates with the past and projects towards the future. It uses language, it makes us communicate. It is that voice, that buzz that tells me "I am".

RIGHT HEMISPHERE

Parallel Processor. Totally focused on the present, here and now. Think in pictures, learn kinesthetically. Information flows simultaneously through the sensory systems as energy. It puts us in contact with the environment and with others through our senses.

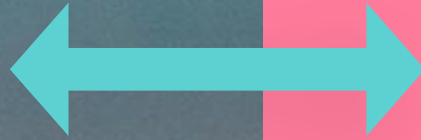
INTEROCEPTION

It is the ability to recognize sensations, stimuli. It is an internal awareness, expressed for example as: a breath, hunger, satiety, a pain, etc. These elements make me understand if everything is okay or if there is something wrong with myself.

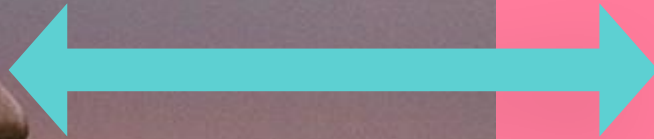
PERCEPTION

It is the ability to acquire awareness of an external reality through the senses. For example: a color, an object, movement, etc. These elements help me understand how I am in the external environment.

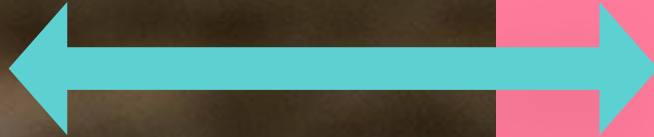




PERCEPTION



FUNCTION, ROLE, OBJECTIVE



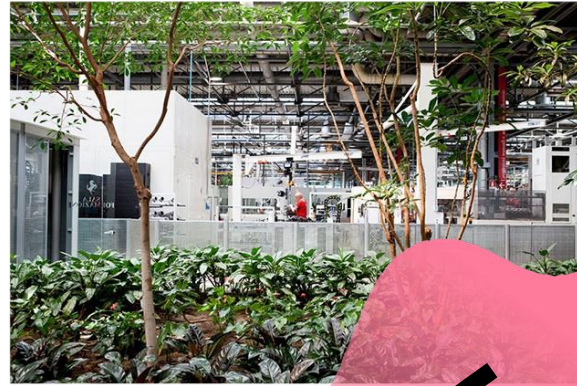
INTEROCEPTION

THE FERRARI SYSTEM

Ferrari, the Italian Excellence that makes the world dream



EXTERNAL:
WE DESIGN AND PRODUCE ALL THE
OUR CARS IN MARANELLO, ITALY,
BUT WE SELL THEM IN OVER 60 MARKETS
WORLDWIDE THROUGH A NETWORK OF 180
AUTHORIZED DEALERS.



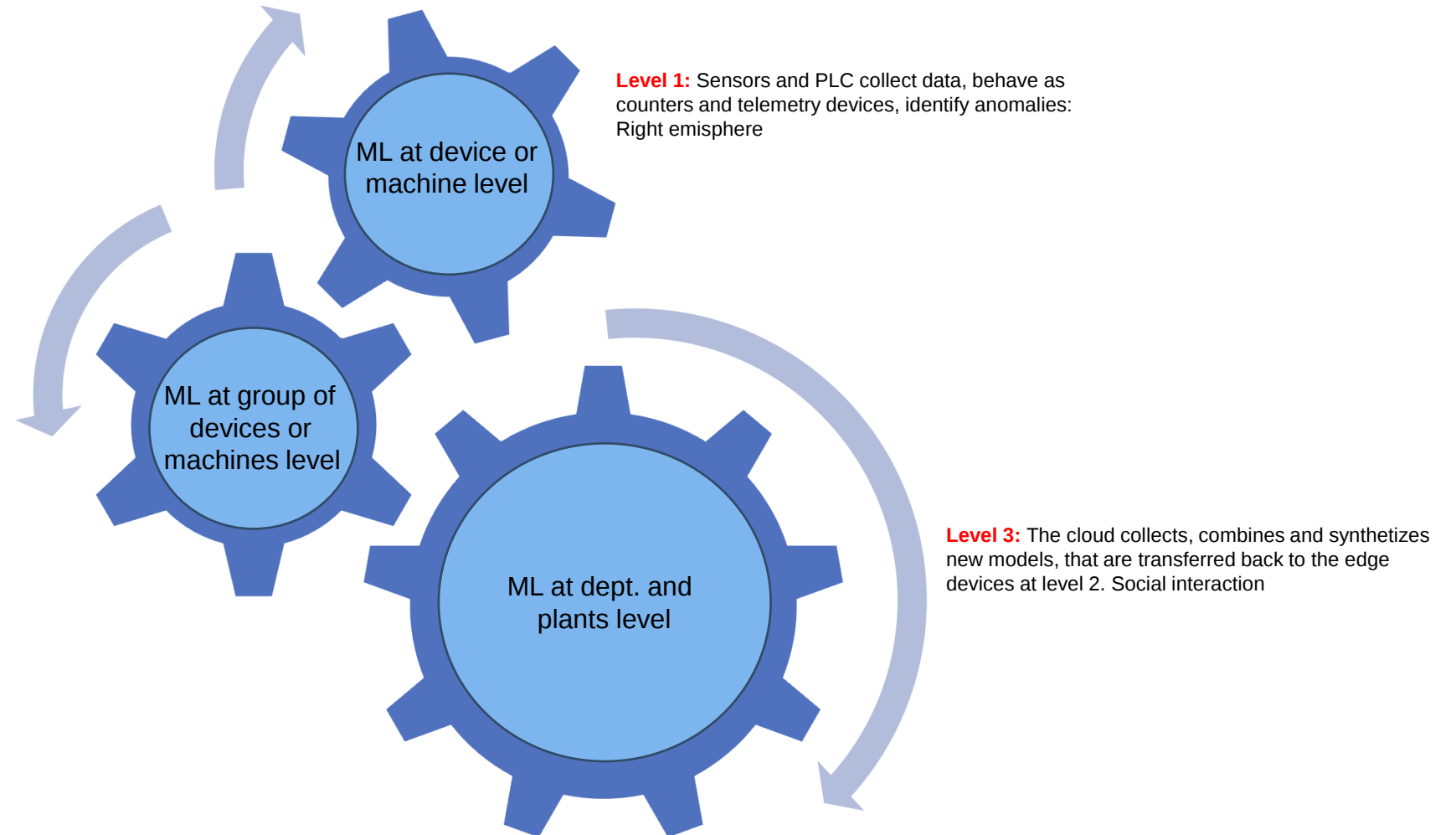
FUNCTION:
BEING FERRARI MEANS BEING PART OF A
UNIQUE TEAM, PROJECTED TOWARDS THE
FUTURE, IN WHICH PEOPLE ARE THE
MOST IMPORTANT HERITAGE.



SYSTEM:
WE BUILD CARS, SYMBOL OF ITALIAN EXCELLENCE
IN THE WORLD, TO WIN ON THE ROAD AND IN THE
WORLD COMPETITIONS. UNIQUE OBJECTS THAT
RENEW THE MYTH OF THE HORSE CLIMBING AND
GENERATE A "WORLD OF DREAMS AND EMOTIONS".

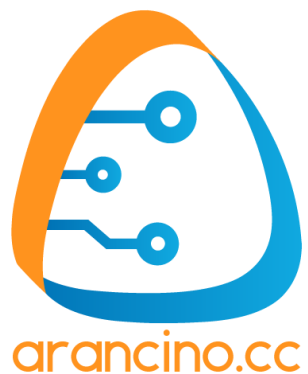


Methodology



Arancino

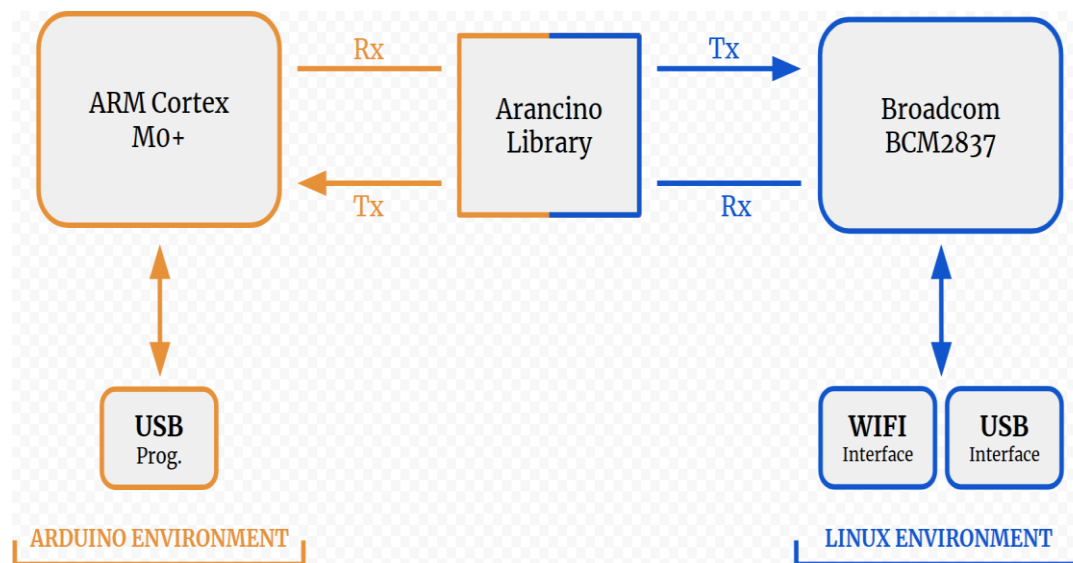
ARANCINO SMART BOARDS



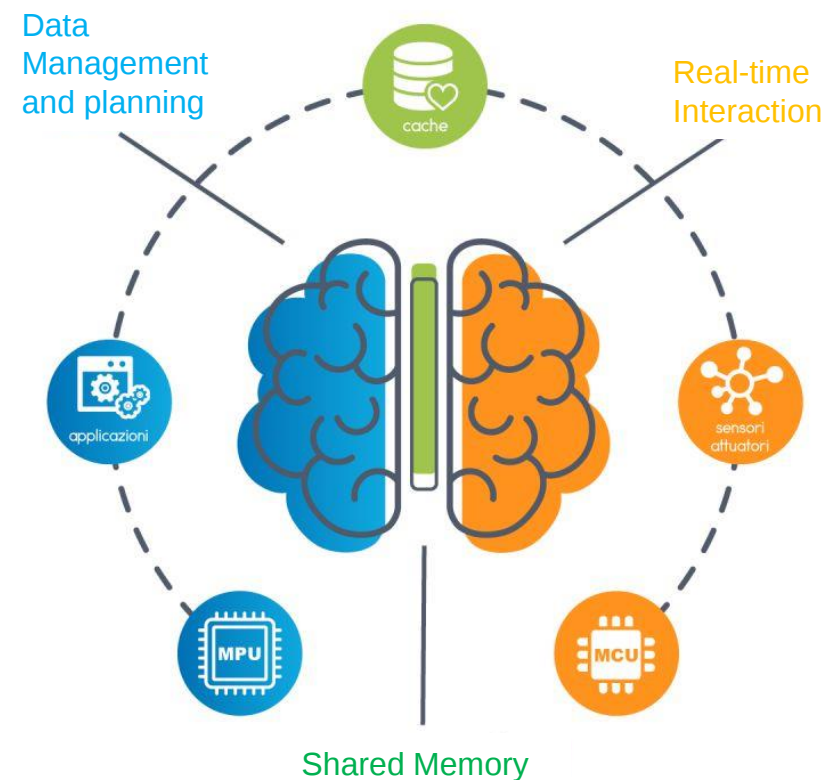
arancino.cc



smartme.io

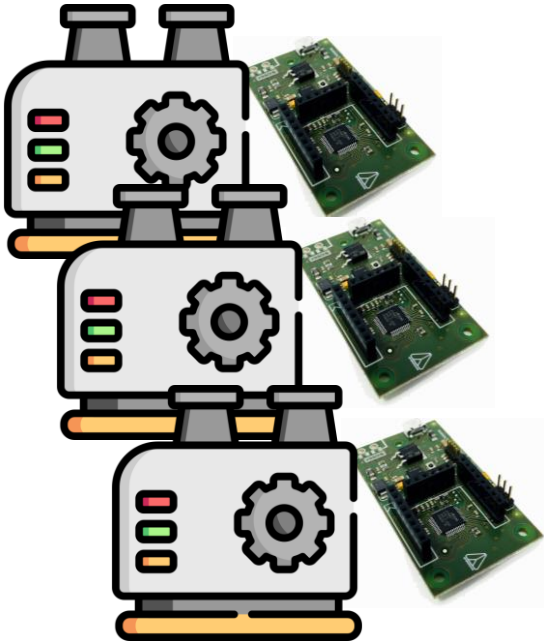


Arancino.cc architecture



From on-field monitoring to IoT applications

Machines with Arancino



Interacting with machines and sensors

Arancino Edge



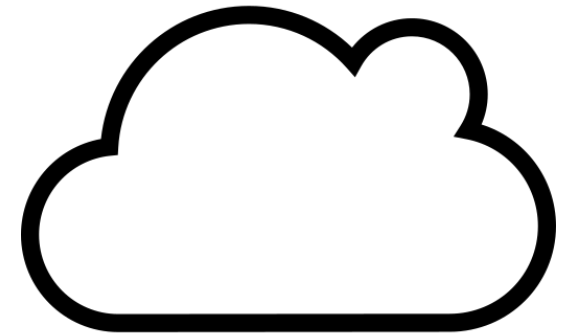
Data collection and first data analysis

Connettivity

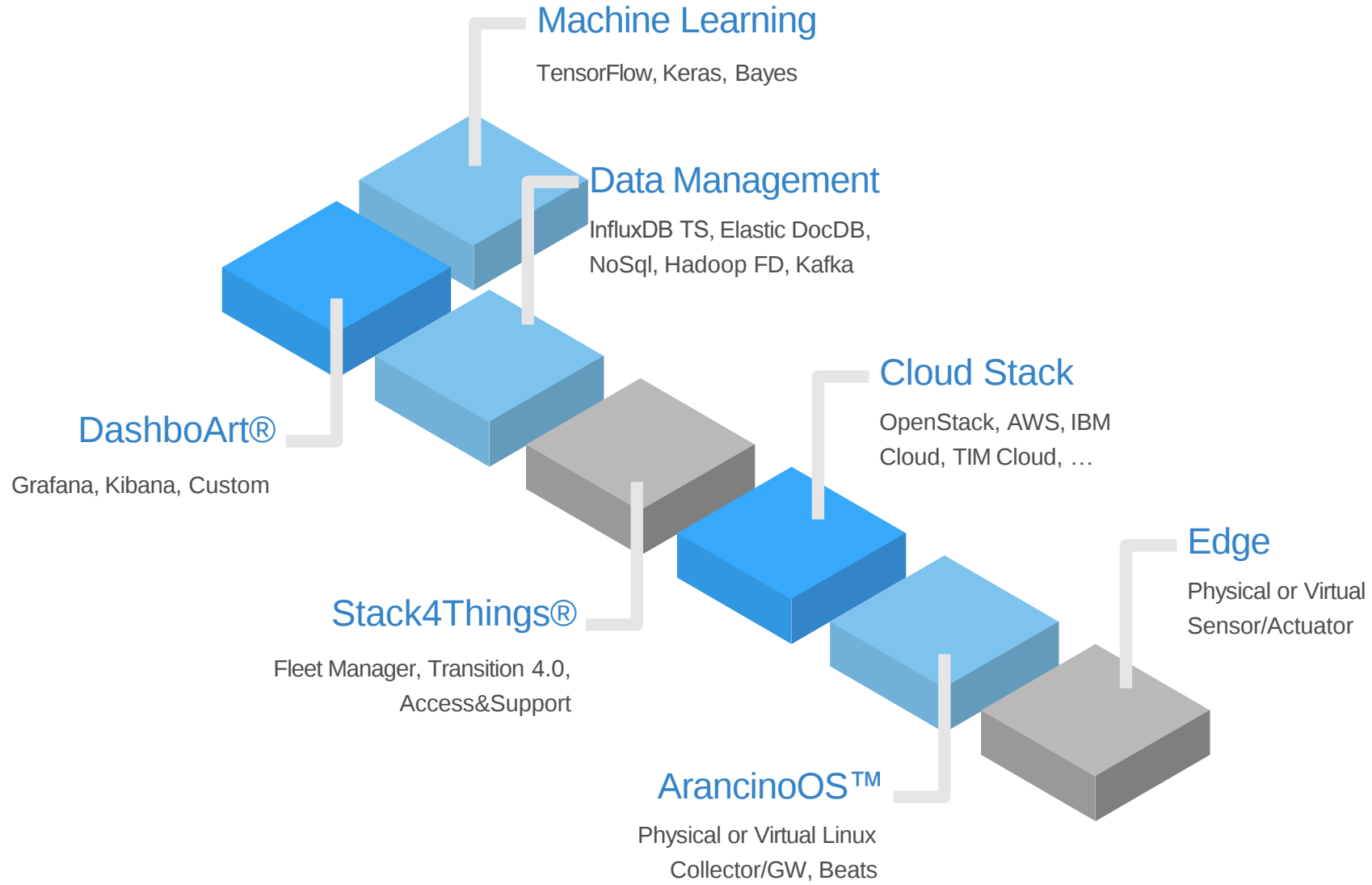


- Mobile EMnify
- LoRa
- Eth/WiFi

Cloud



- Machine Learning
- Data Management
- Device Management:
 - Stack4Things
 - Fleet Manager
- Events & Notify Management



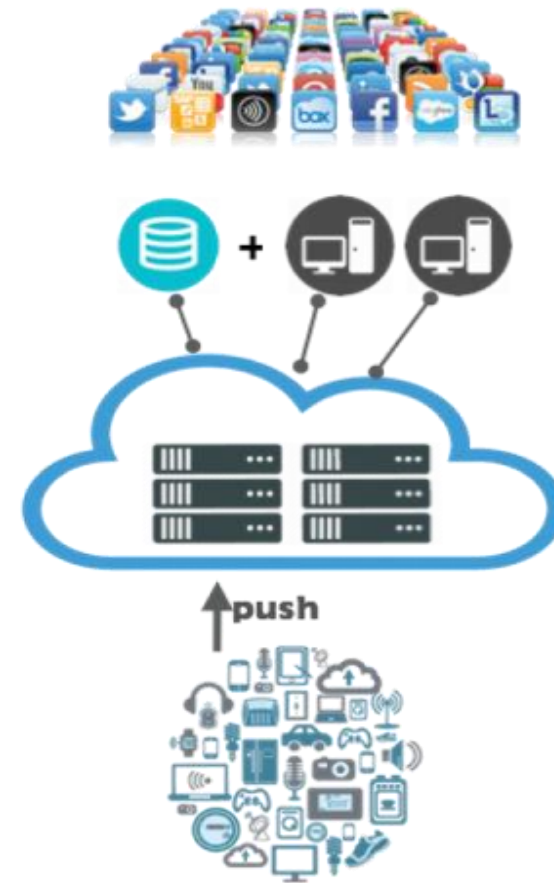
Data-oriented approach

IoT devices send data to the Cloud

Apps is built on top of standard cloud facilities (VMs, storage, network)

Apps makes use of stored (non-real time) IoT data

Indirect, IoT device initiated only, retrieval of actuation commands

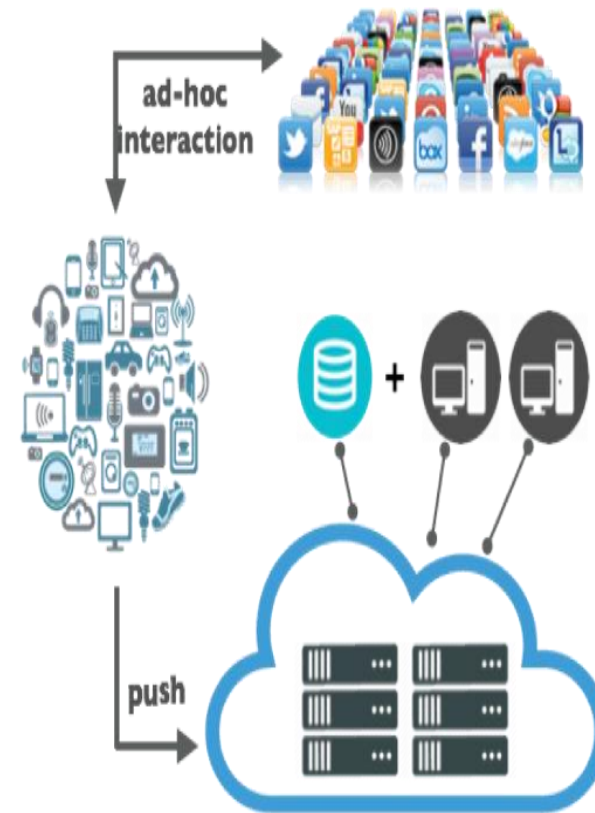


Stack4Things APPLICATION SPECIFIC (VERTICAL APPROACH)

The application uses ad-hoc mechanisms to interact with IoT devices.

No explicit interactions between Cloud components and IoT infrastructure.

Static infrastructure deployment.



I/Ocloud approach

IoT infrastructure as a natural extension of a datacenter

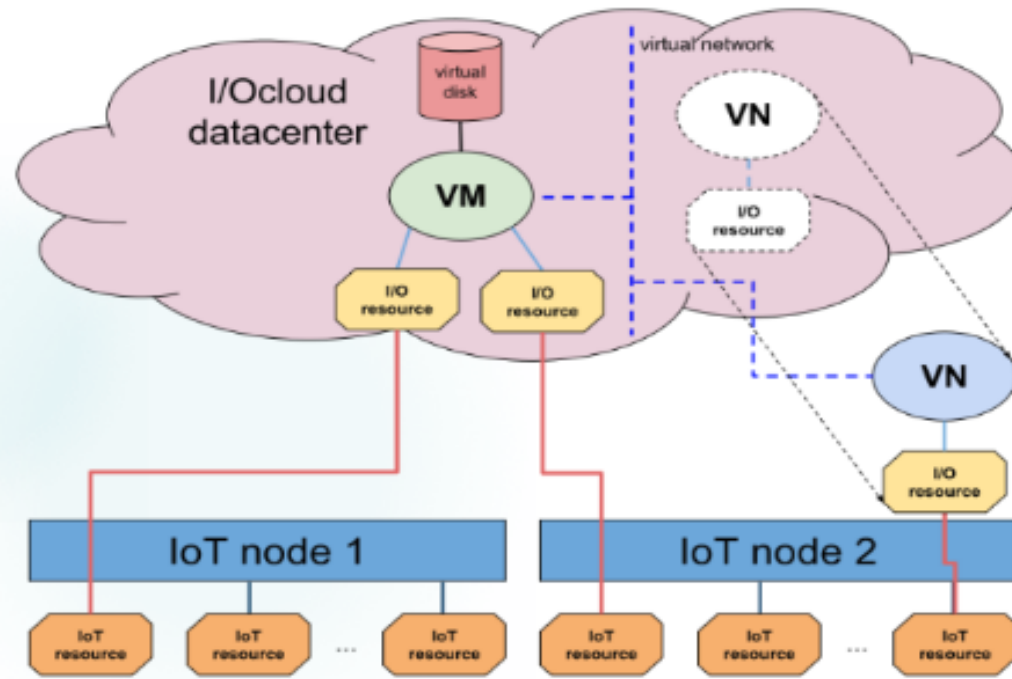
Well-defined Cloud API as a resource management interface

Separation of concerns between infrastructure and application (when needed)

From Cloud to Fog/Edge computing

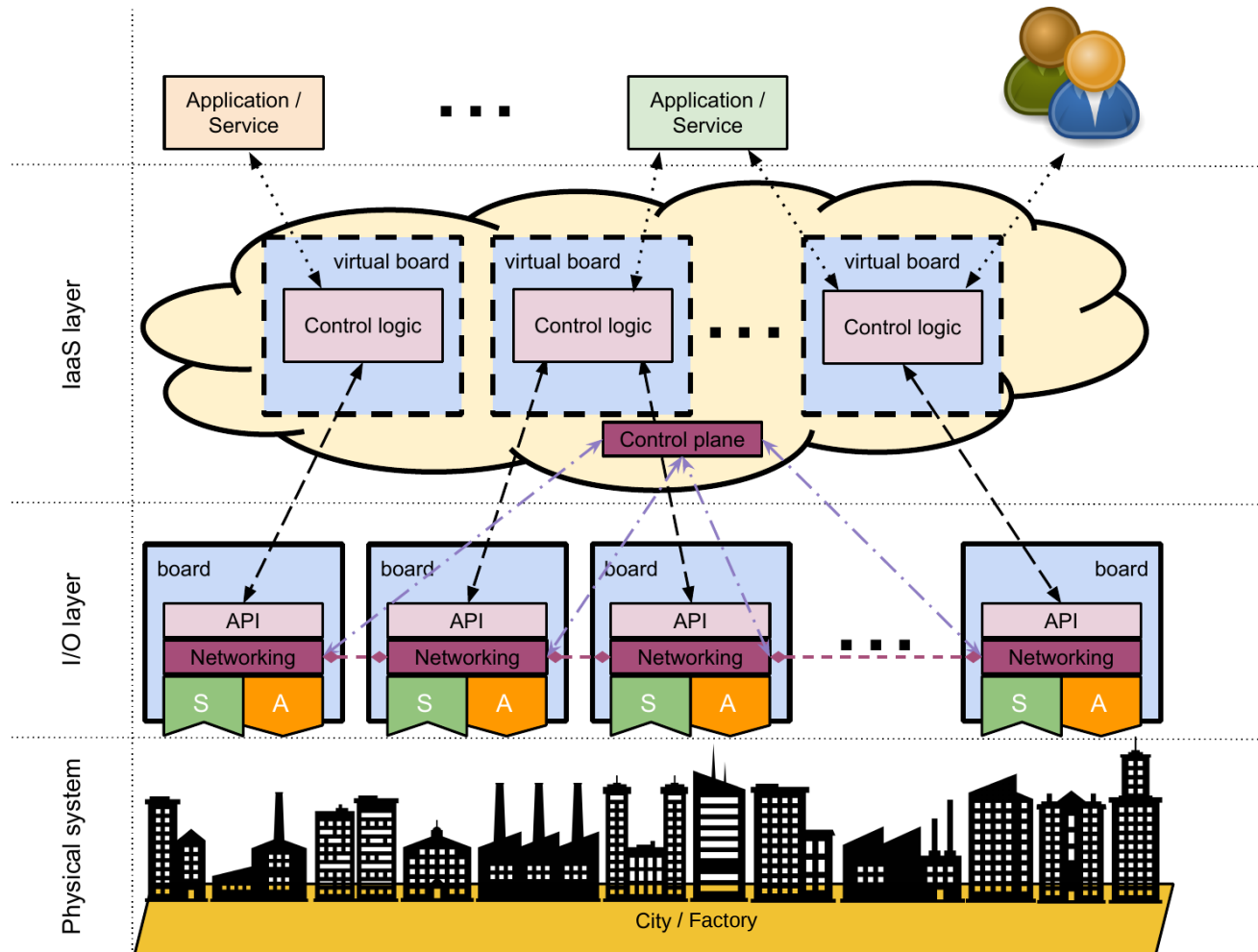
Device computation offloading





Approaches
(to I/O extensions for the Cloud)

Stack4Things SOFTWARE DEFINED CITIES/INDUSTRIAL SITES



Analogy with Software Defined Networking (SDN).

Extends the SD* approach to a cyber city system to enable the re-configuration of the underlying infrastructure.

Several controllers exploit and implement the requested node topologies through generalized rules and according to predefined policies.

Stack4Things S4T & OPENSTACK

IoT resource management service for OpenStack Clouds

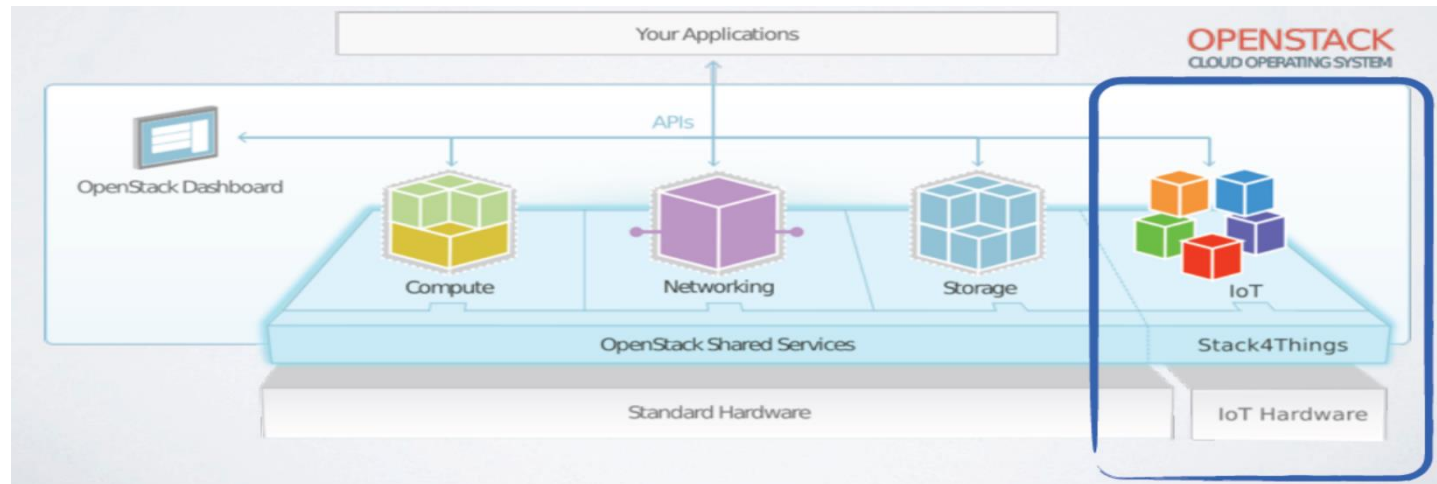
OpenStack (unofficial) project:

Member of the OpenStack Edge Computing group

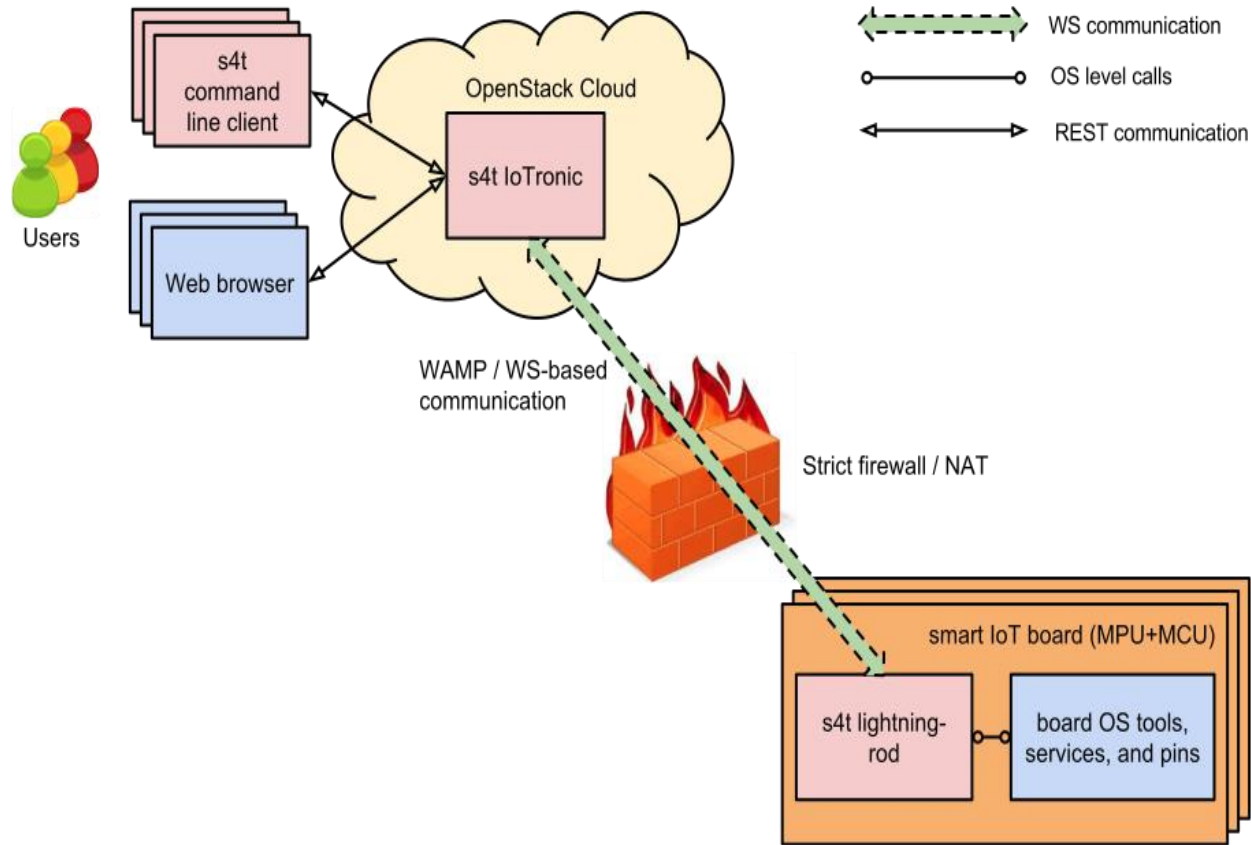
(https://wiki.openstack.org/wiki/Edge_Computing_Group)

<https://launchpad.net/iotronic>

<https://opendev.org/x/iotronic>



Stack4Things HIGH-LEVEL OVERVIEW



IoT scenarios are different from Cloud-based deployments

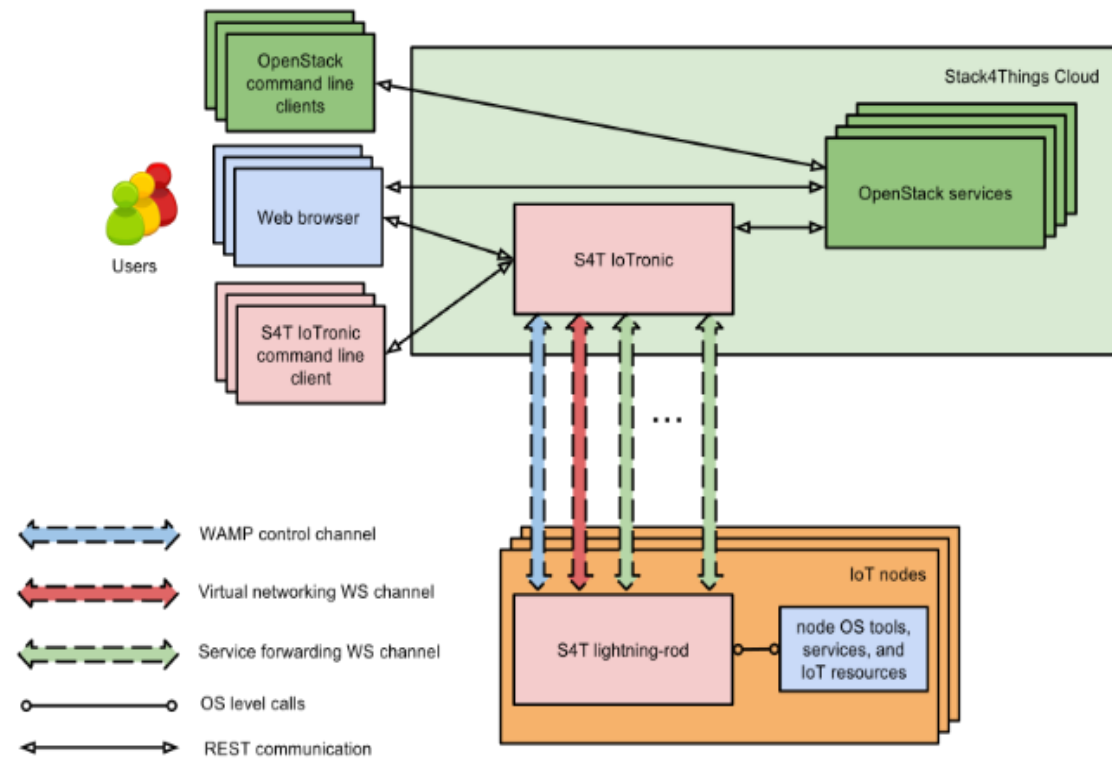
The devices are outside datacenters.

Deployed at the network Edge

Behind networking middleboxes (e.g., NATs, Firewalls)

S4T uses suitable mechanisms to overwhelm the unique constraints of IoT deployments

Stack4Things HIGH-LEVEL OVERVIEW



Use of a
software probe on
the device-side
(lightning-rod)

OpenStack
compliant
service
(IoTonic)

Use of WAMP
and plain
WebSocket
control
channels

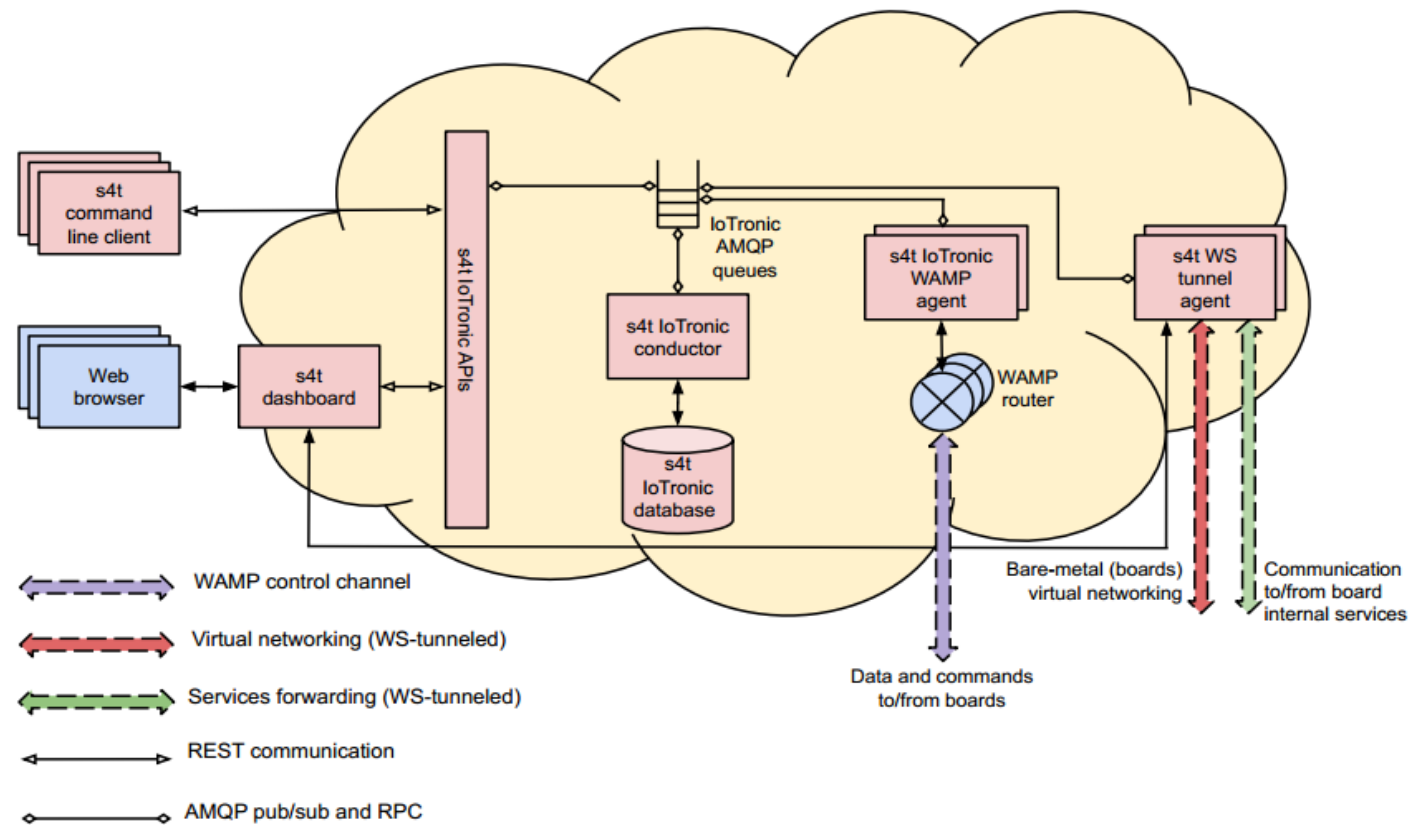
REST interfaces

Stack4Things CLOUD-SIDE ARCHITECTURE

Infrastructure management and interaction services exposed as RESTful APIs.

The Horizon dashboard as control surface for any kind of resource, including IoT-borne ones.

Deep integration with OpenStack (OS) frameworks and services, i.e., Cloud-side functionalities.



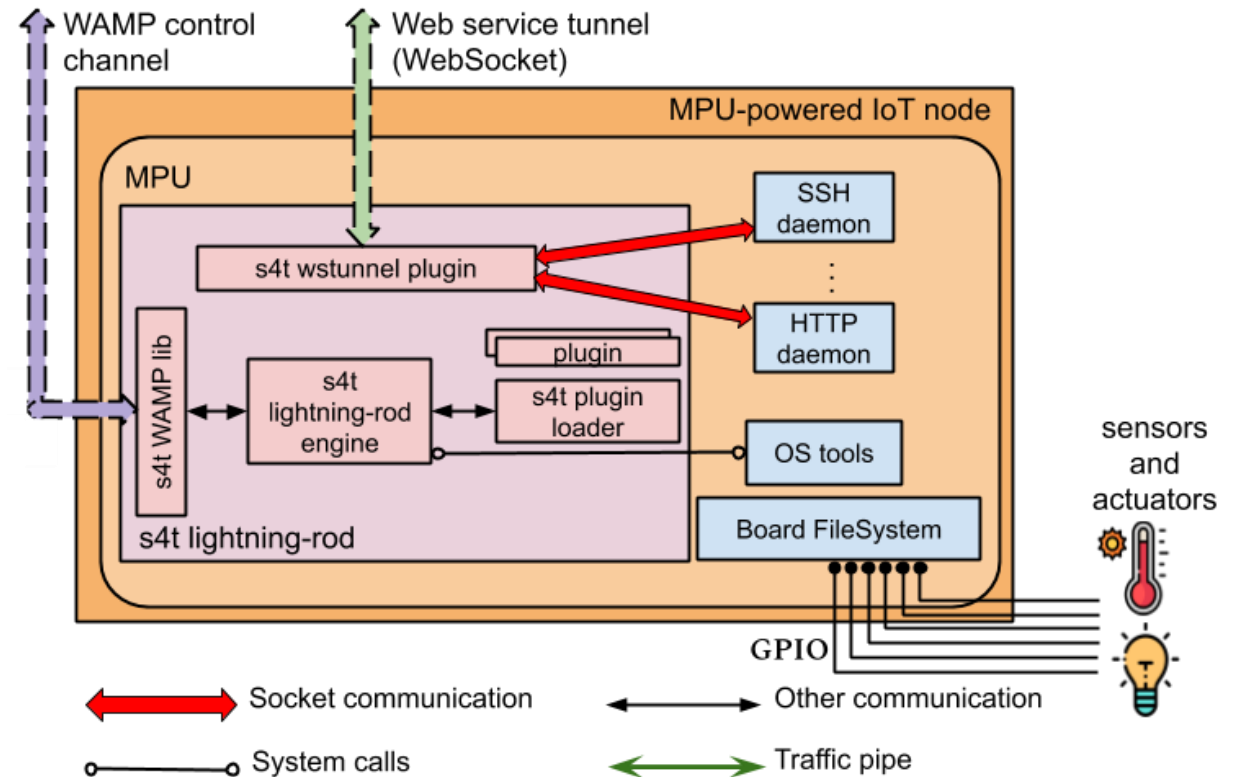
Stack4Things BOARD-SIDE ARCHITECTURE

The Lightning-Rod engine is the core of the device-side software architecture.

The engine interacts with the Cloud through WAMP protocol (i.e., pub/sub and RPCs)

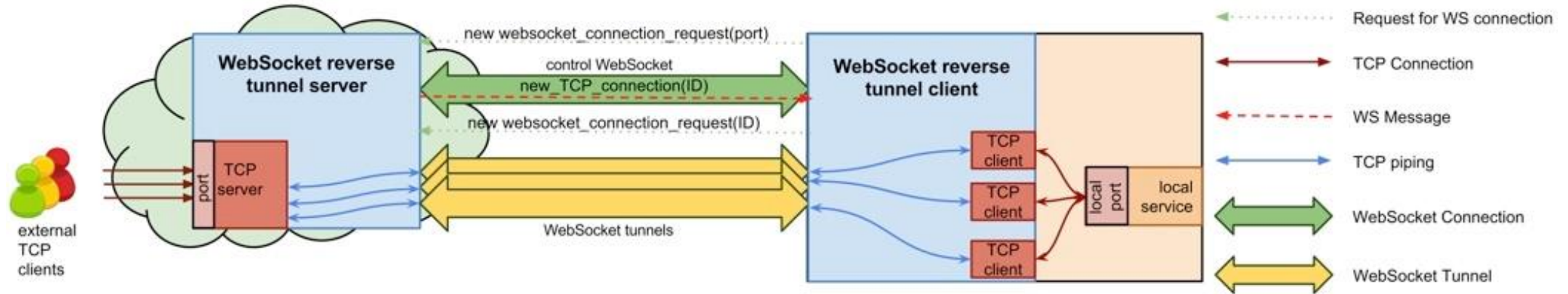
The WebSocket libraries allows the engine to act as a WebSocket reverse tunnelling server.

Custom plugins can be injected from the Cloud in order to implement specific user-defined commands



The figure shows the core services of IoTronic. Advanced functionalities are deployed by adding other components to this architecture.

Stack4Things SERVICE FORWARDING



A user can access, remotely, his/her services running on the device using the Cloud IP address.

Each service has its own (secured) Websocket tunnel.

Requests received on a specific port on the Cloud are forwarded through a Websocket tunnel.

Example:

An SSH daemon running on the board (i.e., port 22) can be exposed through the public IP address of the Cloud and a specific port.

Stack4Things VIRTUAL NETWORKING IN IOT

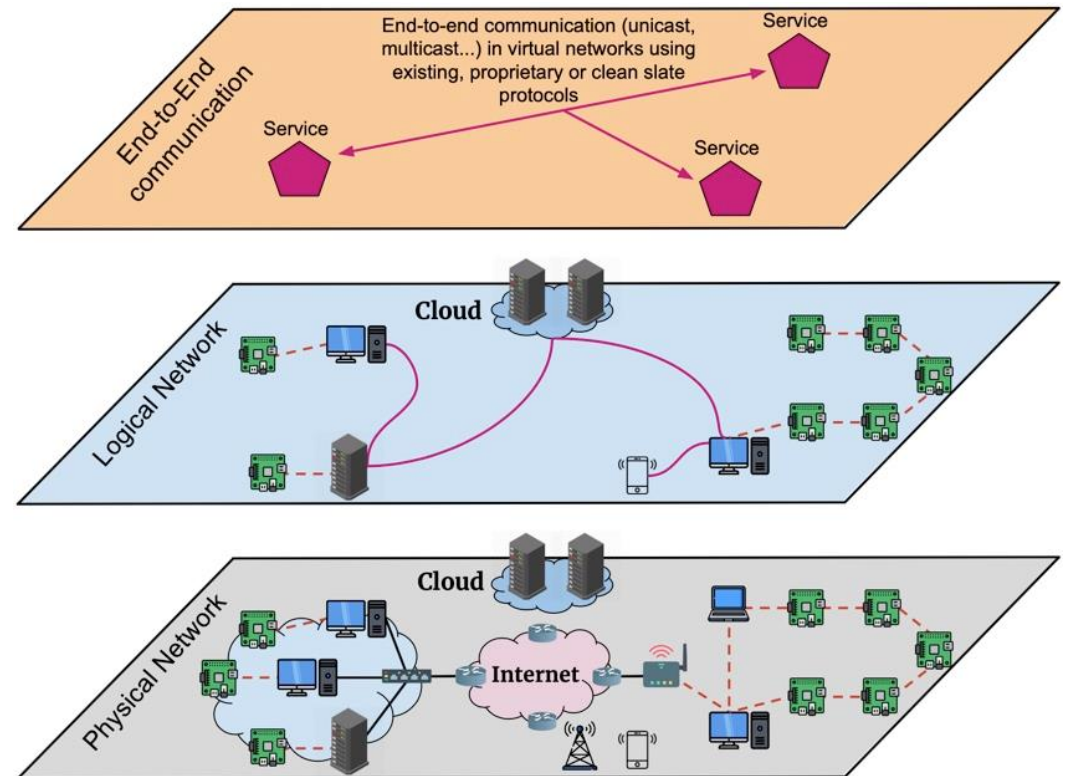
Virtualization both at the network and datalink layers enables flexible overlay networking topologies.

Infrastructure-agnostic applications.

Enable the creation of network overlays between geographically dispersed devices, we integrated Neutron, the networking subsystem of OpenStack, with our S4T middleware.

Extending the scope of applicability of service discovery protocols (e.g., AllJoyn).

Virtual networks may span both (datacenter-hosted) VMs and virtual IoT devices.



Stack4Things VIRTUAL NETWORKING IN IOT

Integration of S4T with the OpenStack Networking subsystem, Neutron.

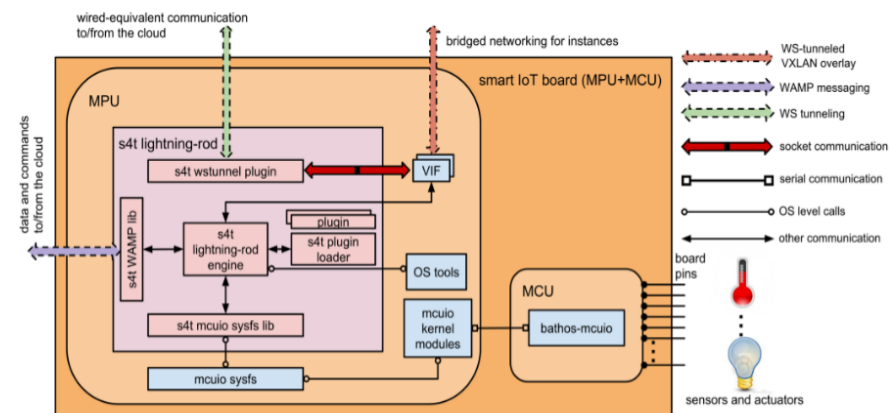
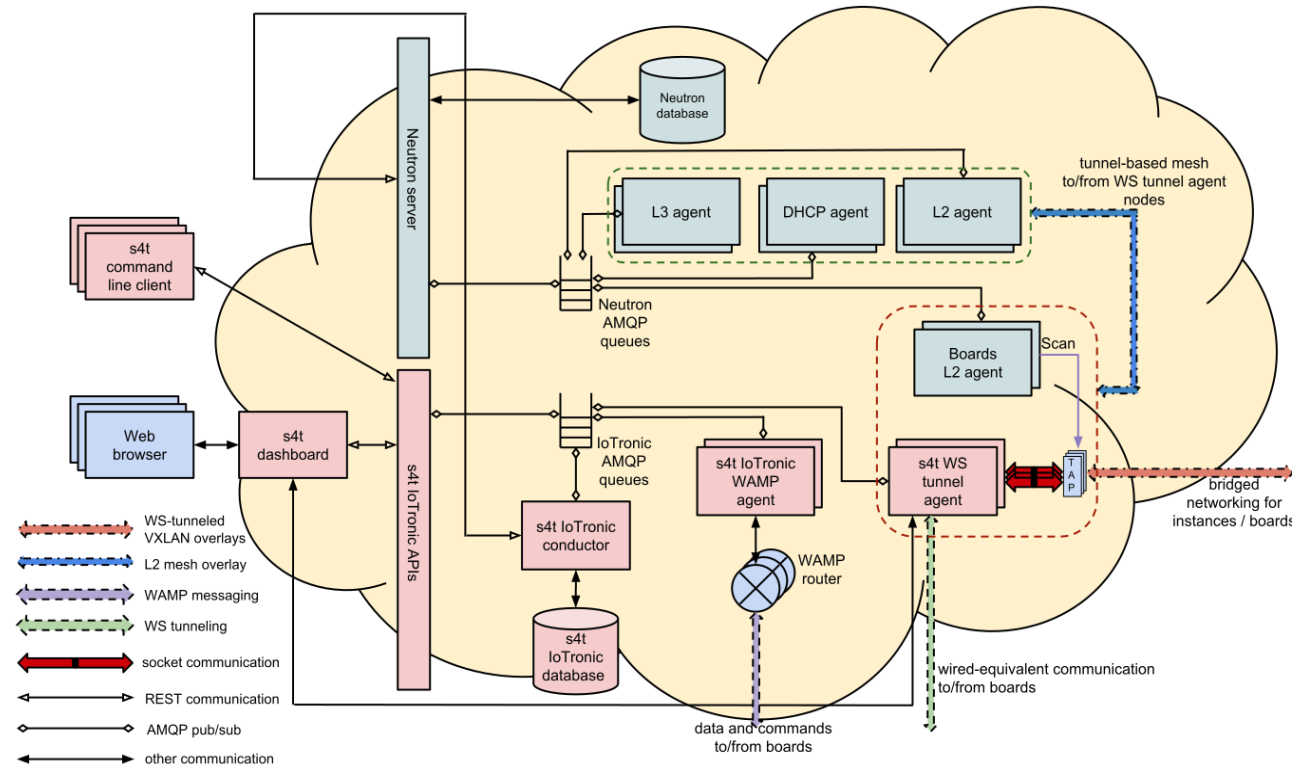
Extending Neutron capabilities to deal with IoT deployments constraints.

Boards are totally unaware about network virtualization duties and Neutron.

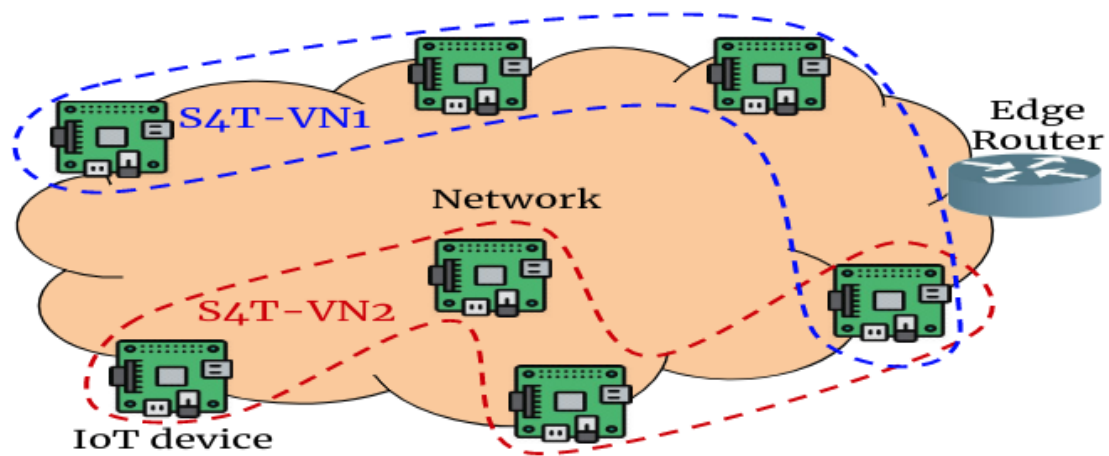
Virtual Networking equipment (e.g., virtual switches) are deployed on the Cloud.

Only virtual interfaces (i.e., TAP class devices) are created on the devices.

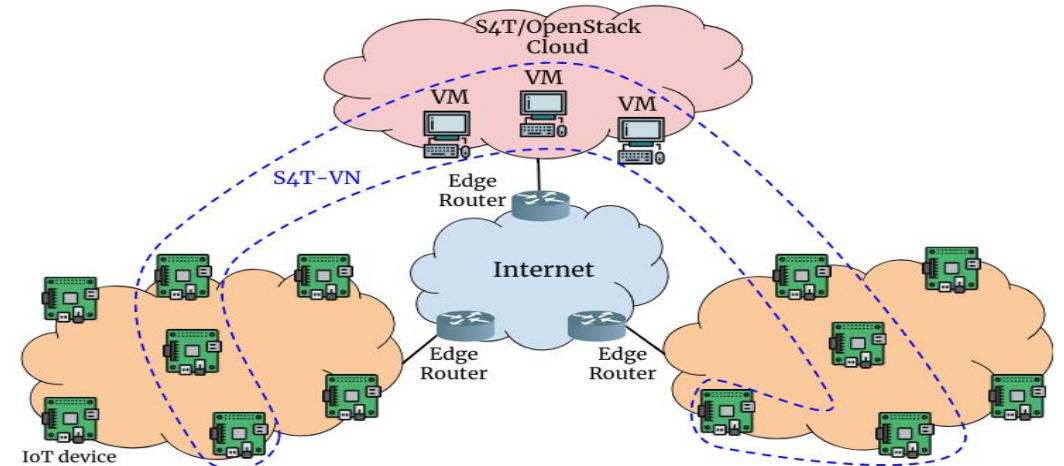
The overall footprint of the solution is inherently lightweight for the boards.



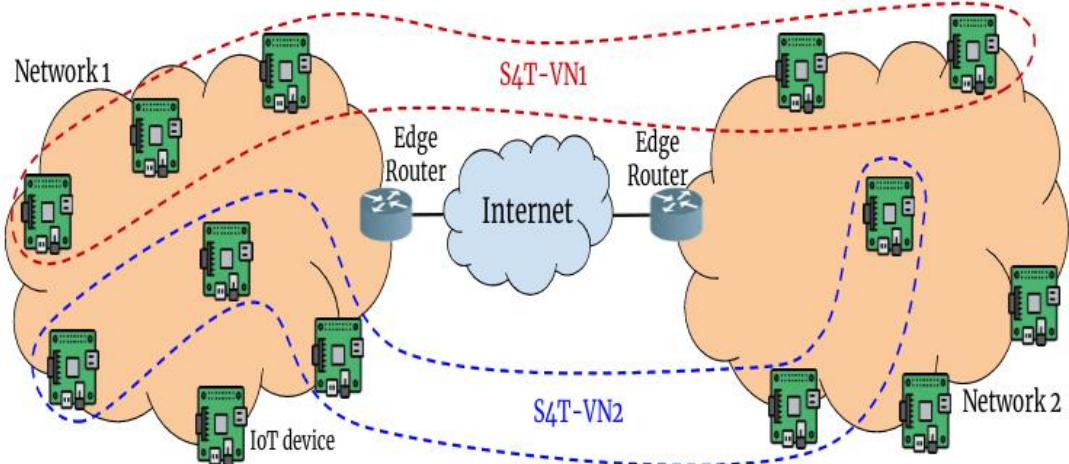
Stack4Things VIRTUAL NETWORKING IN IOT



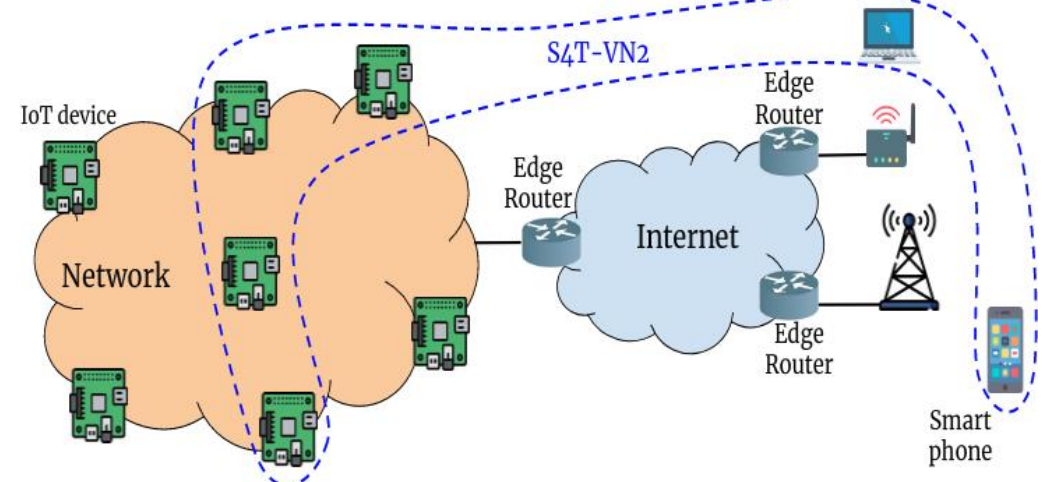
USE CASE 1



USE CASE 3



USE CASE 2



USE CASE 4

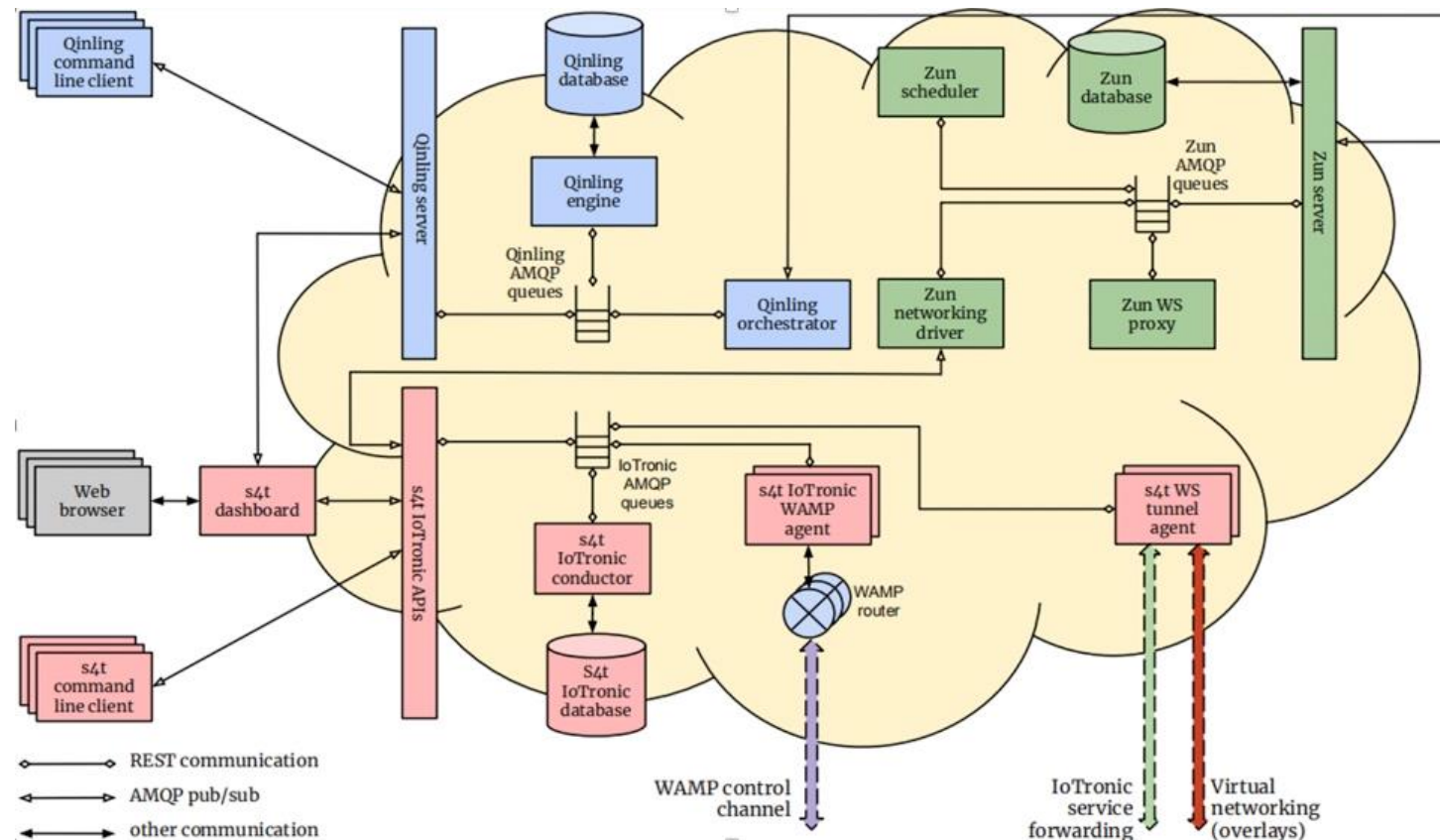
Stack4Things EDGE FUNCTION-AS-A-SERVICE (FaaS)

S4T provides the capability to conceive applications involving IoT devices based on the FaaS/Serverless paradigm.

Functions can be injected on remote IoT devices and then executed/triggered by particular events (i.e., event-driven).

We make use of the Cloud-oriented OpenStack services Qinling (Serverless subsystem) and Zun (containers management subsystem).

IoTronic is used as a networking driver for Zun/Qinling.



Stack4Things EDGE FUNCTION-AS-A-SERVICE (FaaS)

Use case: Create IoT pipelines/dataflows involving geo-distributed devices and their hosted resources (i.e., sensors and actuators)

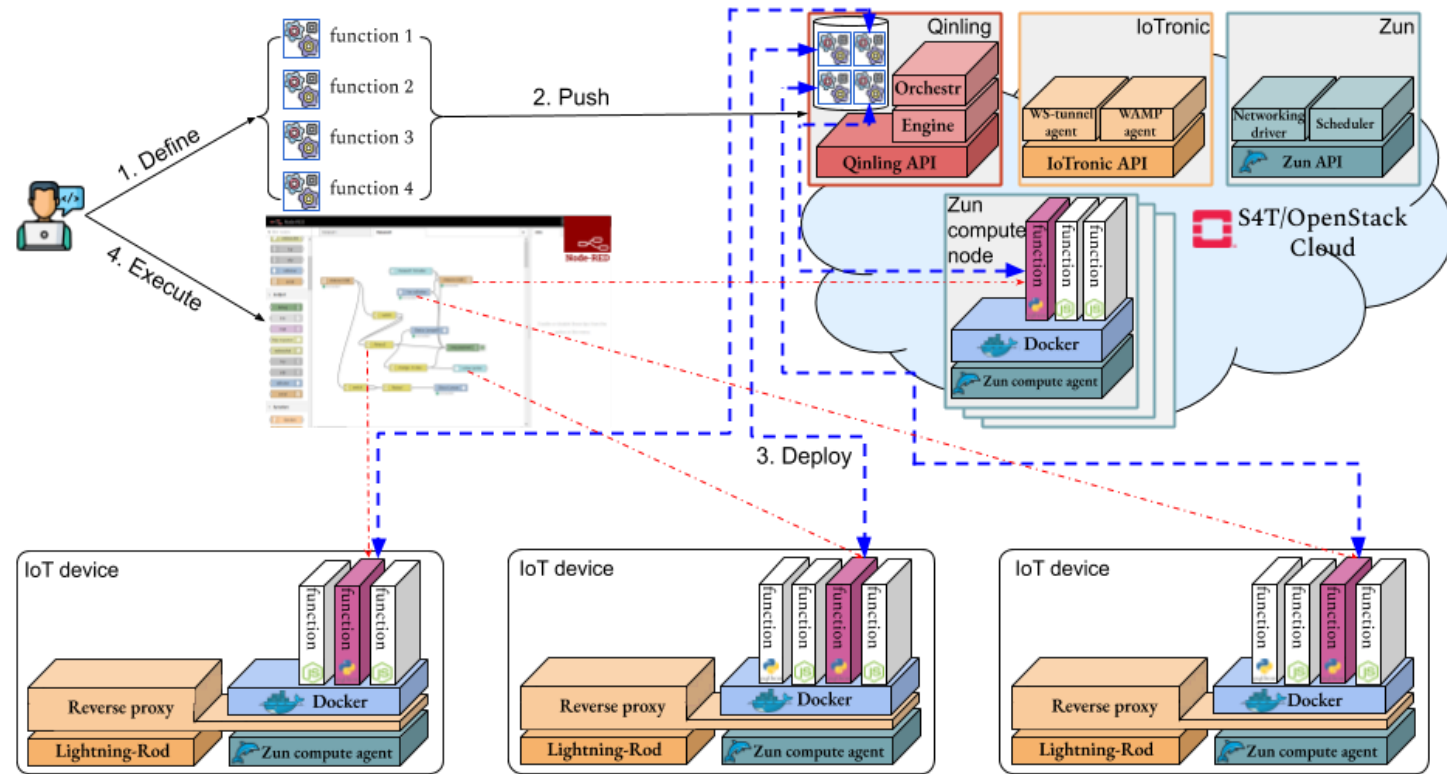
Node-Red blocks are instantiated on the devices as FaaS functions.

Functions deployed on the Cloud-side can be also involved (i.e., more compute resources).

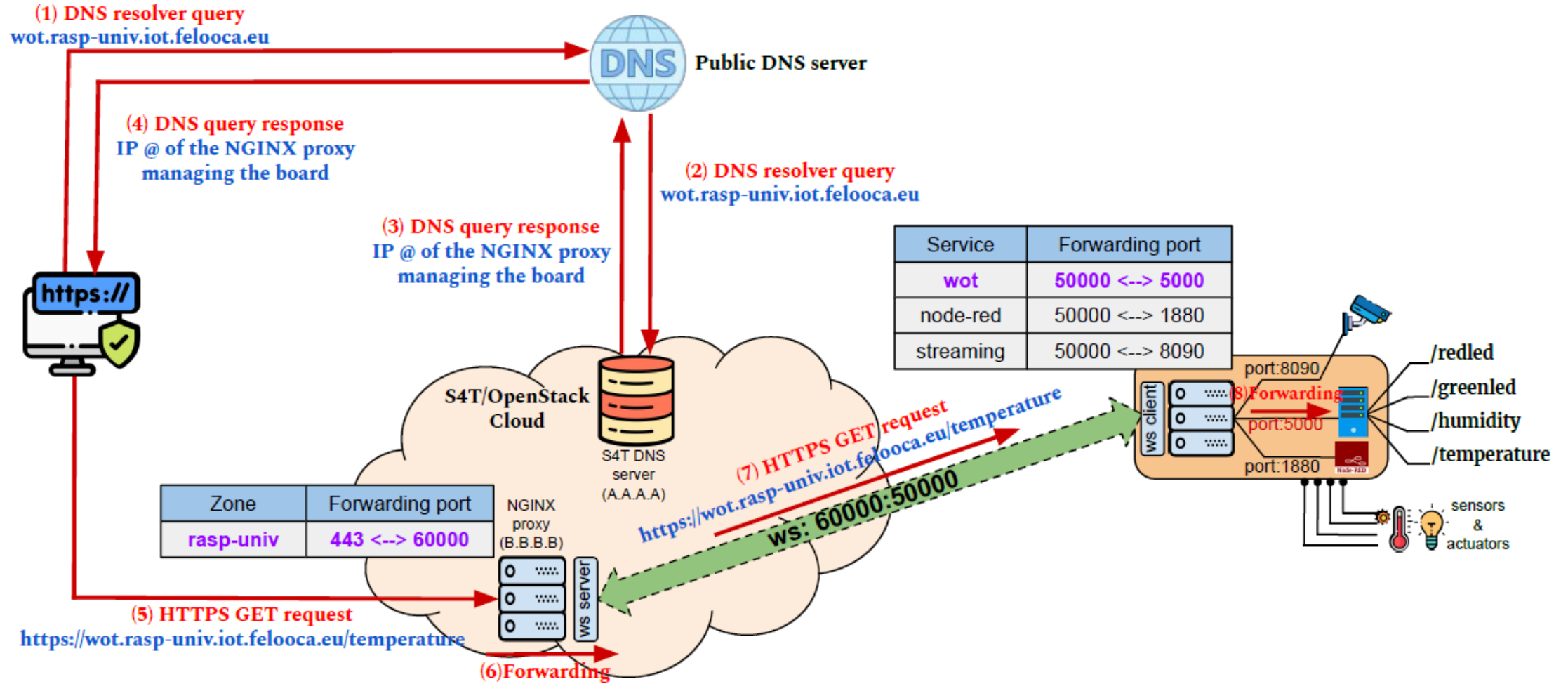
OpenStack/Qinling is used as a centralized repository for the custom actions.

For applications involving ‘serverless’ logic in the cloud, S4T can provide a standard way to package, deploy and manage functions/actions across the cloud and the edge.

You can conveniently develop custom logic for the IoT devices in programming languages other than JavaScript (e.g., Python).

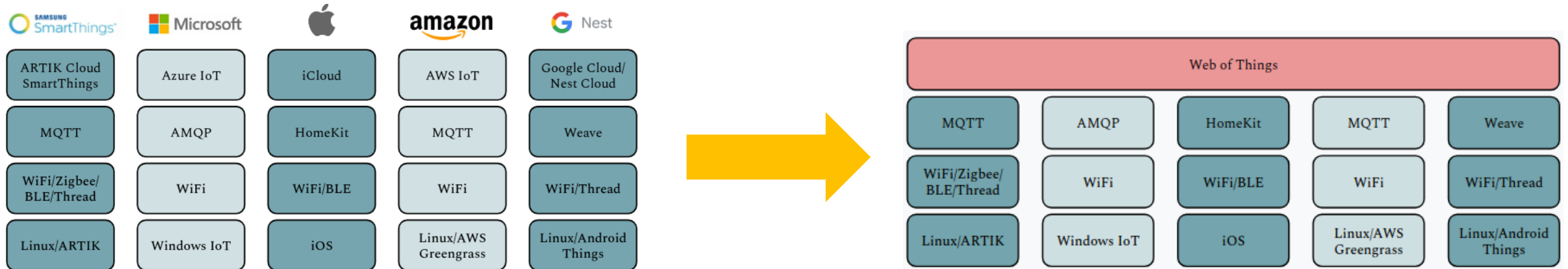


Stack4Things WEB OF THINGS



Stack4Things WEB OF THINGS

Everything as a Resource



Use case: Stack4Things Web services are used to enable the Web of Things paradigm (WoT).

The WoT paradigm aims at making IoT devices/resources an integral part of the Web.

By exposing Web servers running on the IoT devices, we can expose sensors and actuators as Web resources.

Smart things become easier to build upon popular Web languages (e.g., HTML, Python, JavaScript, PHP) can be used to easily build applications involving smart things

Demo: <https://wot.rasp-univ.iot.feloooca.eu/>

All interactions here are HTTPS based.

Fleet Manager
Welcome,
admin

THINGS

- Control Room
- Scenarios
- Projects
- Things
- Gateways

MANAGEMENT

- IAM
- File manager

SERVICES

- Cloud services
- IoTonic testbeds

[Actions](#)

Thing Today Center Shopping Mall

Your role in this project: superadmin

Details

Id: 9
 Codename: uffici-smartme
 Label: Today Center Shopping Mall
 Type: building
 Project: Environmental Stations [Zaia Angelo]
 Install Date: 2020-11-22
 Latitude: 38.143310
 Longitude: 15.524650
 Altitude: 30.000
 Metadata:
 Devices: 3

Map

Visualizza mappa ingrandita

Information

ID	Codename	State	Model	Actions
e9380315-be46-4876-9d53-9ed5c56dbbf3	ws-arancino	maintenance	Arancino	✔ ✖
d5891390-4f88-484f-b4e4-e5bc38830866	sme-ws-0001	maintenance	Arancino	✔ ✖
174cac4af-a083-47eb-B9d0-caa186a8e6dc	es-arancino	operative	Arancino	✔ ✖

[Add new](#)

Files

Management

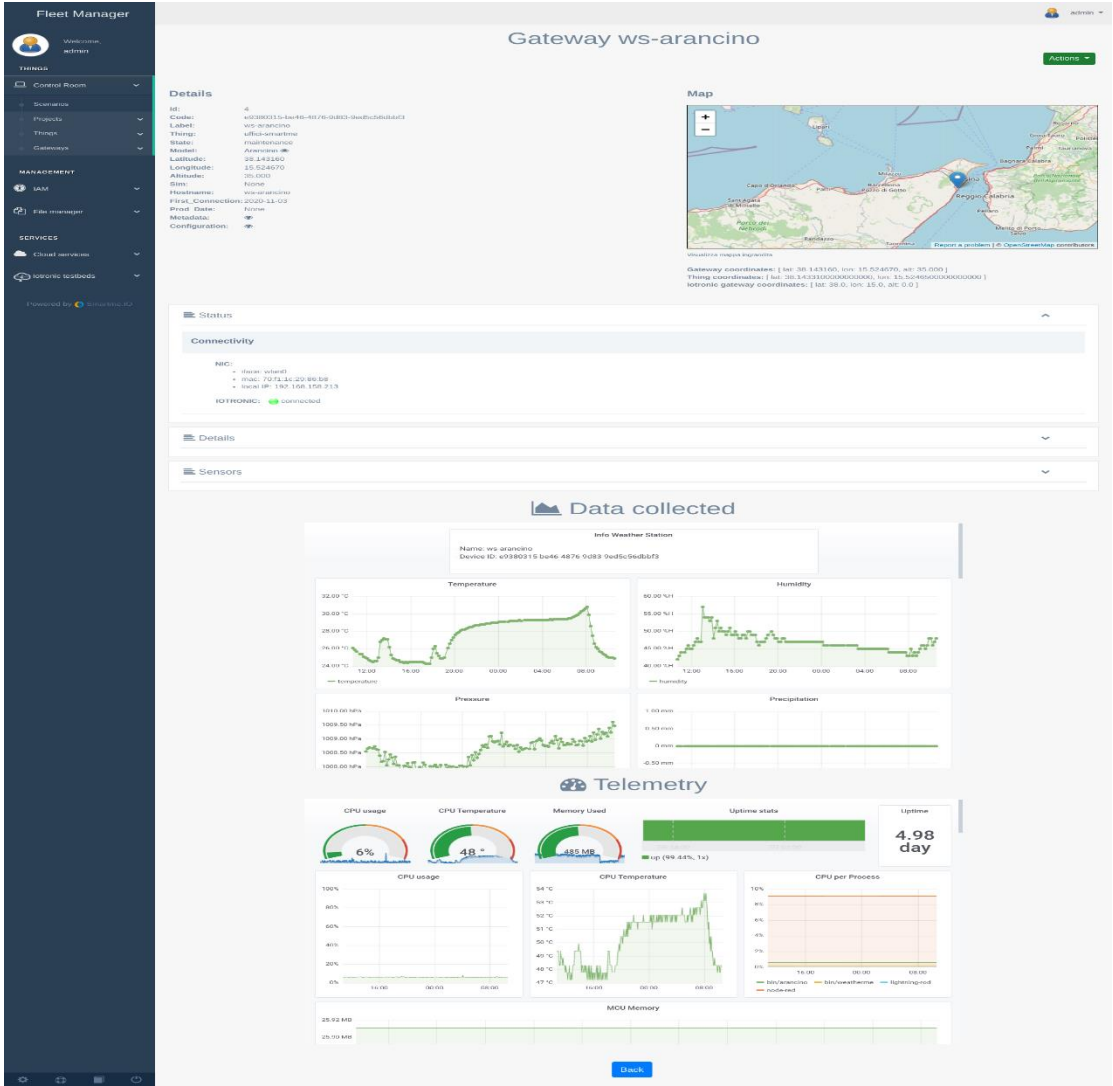
Change devices state

Choose a state:

--- SELECT STA ---

Apply

[Back](#)



OUR CLIENTS



TRAILERS

FIRMWARE + HARDWARE + MGMT CLOUD



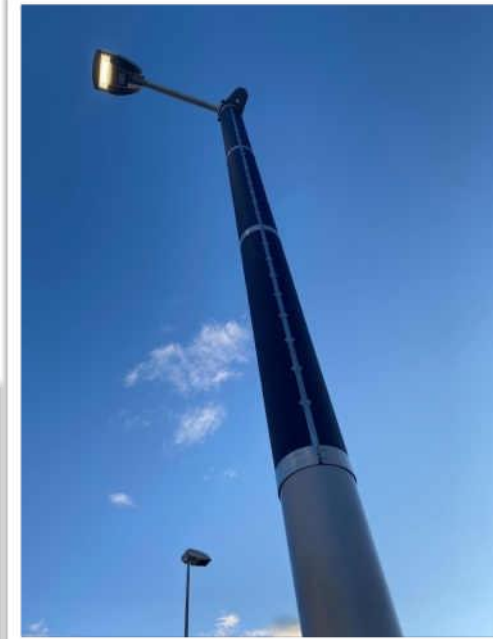
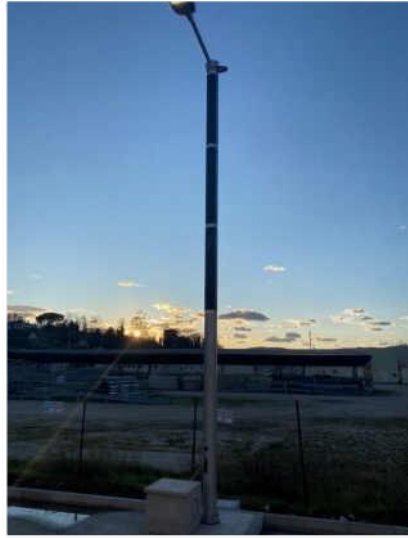
MEDICAL DEVICES

FIRMWARE + HARDWARE

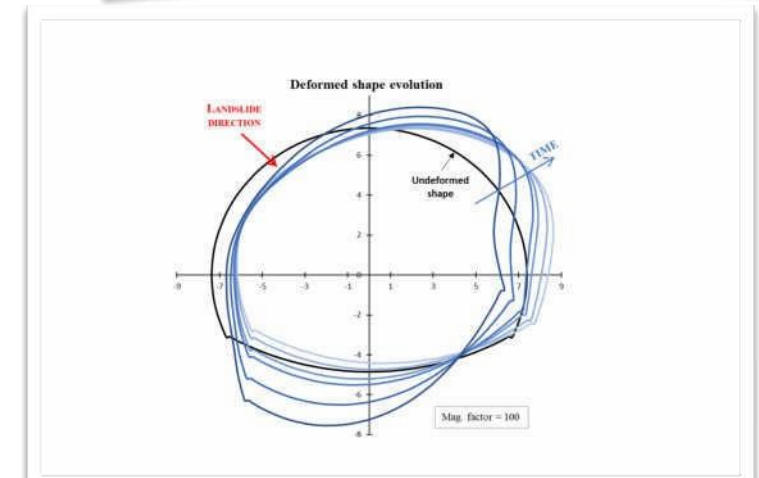
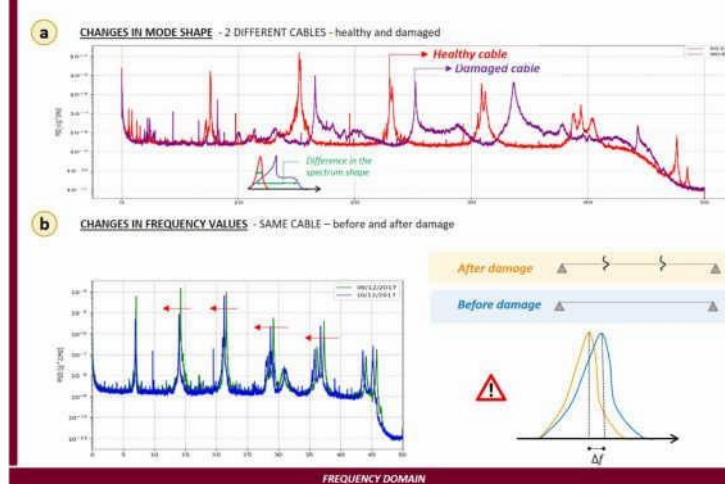
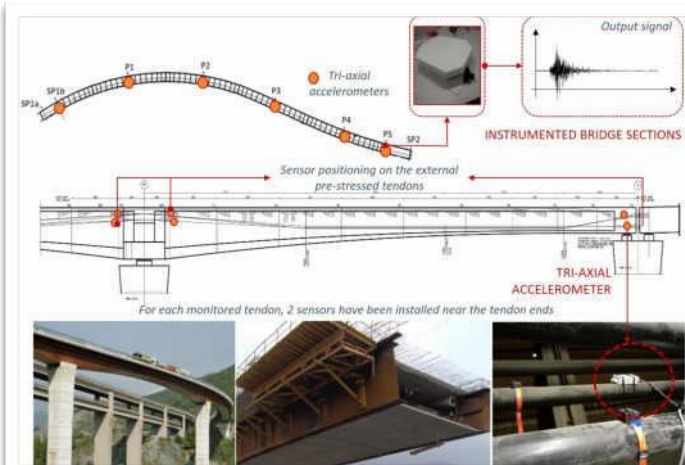


SMART LIGHTING

FIRMWARE + HARDWARE + MGMT CLOUD

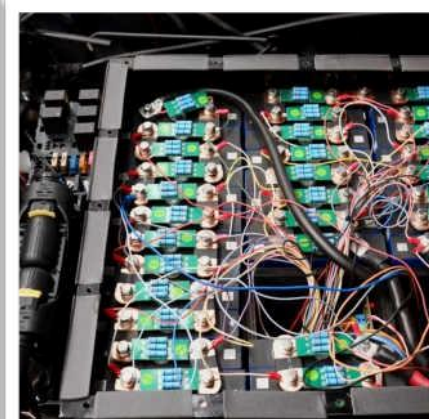


INFRASTRUCTURES MONITORING



ELECTRIC CARS

FIRMWARE + MGMT CLOUD



FOOD INDUSTRY

FIRMWARE + MGMT CLOUD

PULEO
LEADING WINERY MANUFACTURER.



PREDICTIVE MAINTENANCE

FIRMWARE + HARDWARE, ML



#SmartME services TOO(L) SMART



TOO(L) smart is a **reuse** and evolution of the #SmartMe “good practice” that involves **TORINO** **PADOVA** **MESSINA** **LECCE** and **SIRACUSA**

The goal of project is to transform urban systems into a network of objects capable of taking an active role, interacting with each other, with citizens and with the PAs thanks to the paradigms of the Internet of Things and Cloud Computing.



#SmartME services TOO(L) SMART

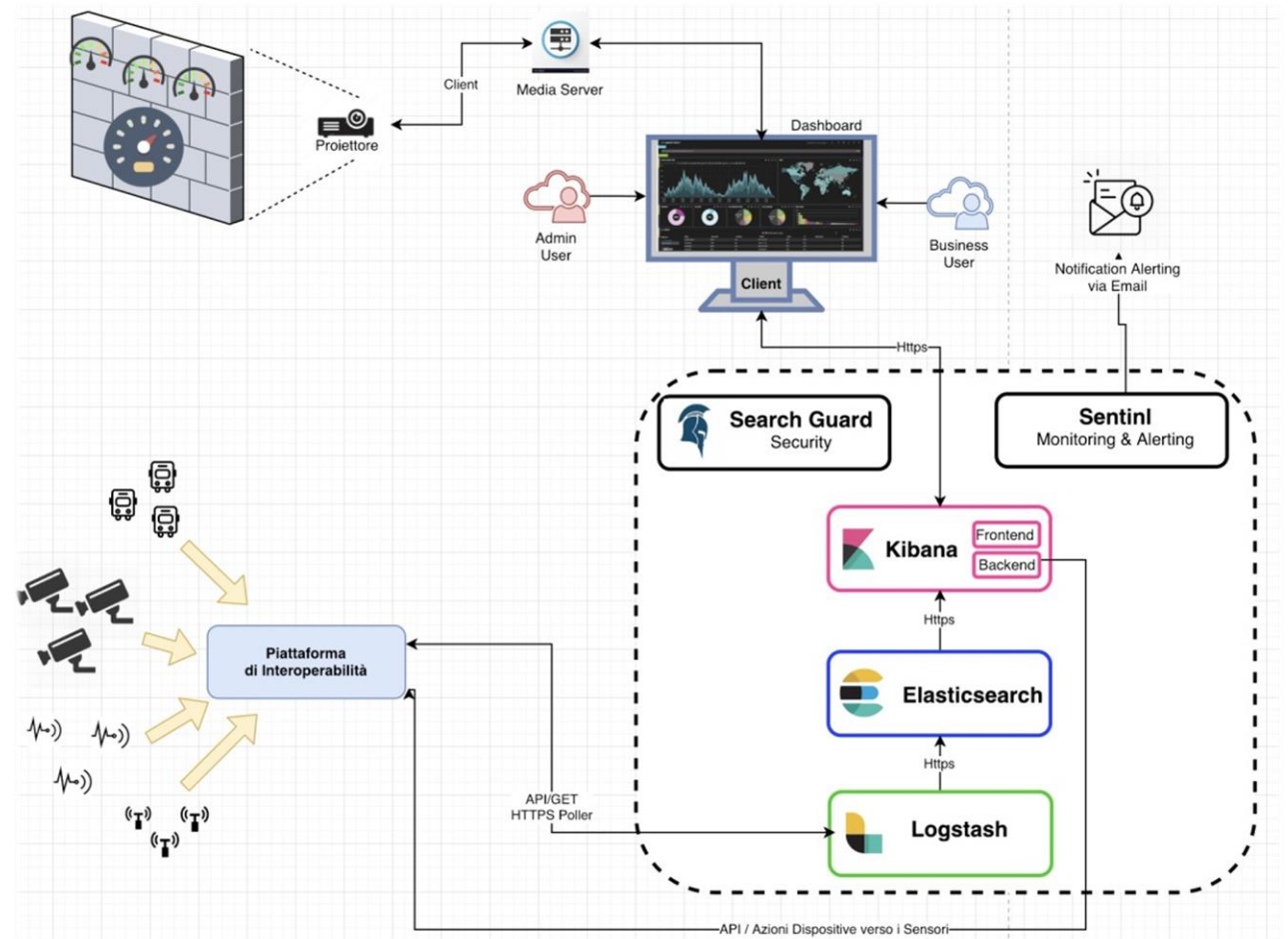


Budget: € 684,450.00

- CINI coordinates the dissemination of good practice at national level.
- Technical support is provided by the startup *smartme.io*
- Evolution: Benevento, Montechiarugolo, Bari, Tangier

- TOO(L) smart is based on (and evolves) the #SmartMe IoT Platform
- #SmartME was born as a crowdfunding project for the construction of an infrastructure of smart services within the city of Messina.
- The basic technological requirements are based on the "open source" paradigm therefore, "open" solutions have been adopted for software, hardware and data.
- Stack4Things is the framework used for IoT devices management. it constitutes an evolution of OpenStack.
- The reference hardware adopted is based on the Arancino board, which integrates the Raspberry PI compute module and the Arduino control module in a single device.

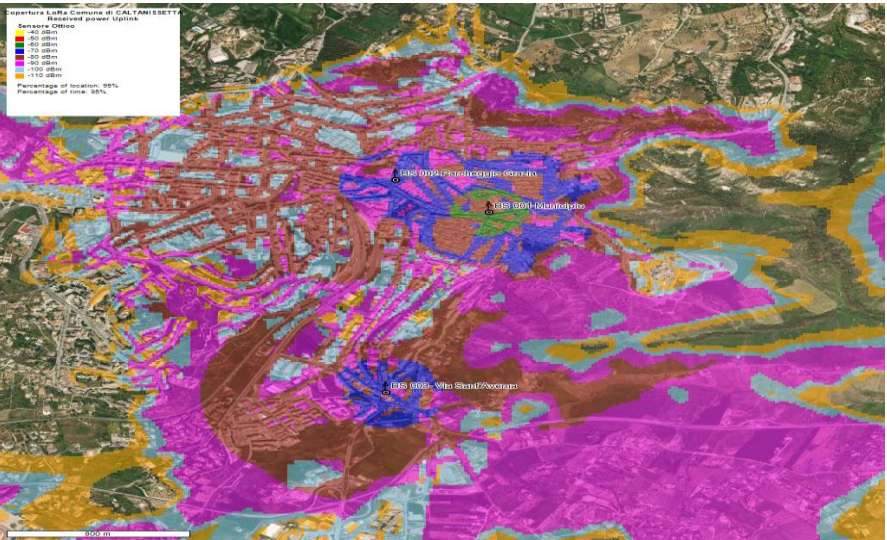
Lorenteggio area - Milan



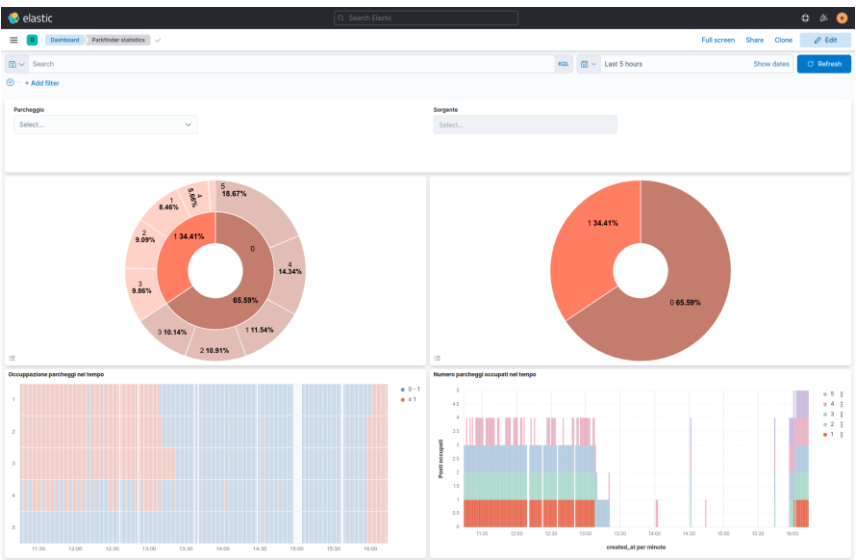
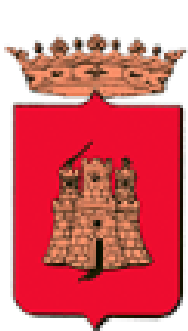


City of Caltanissetta

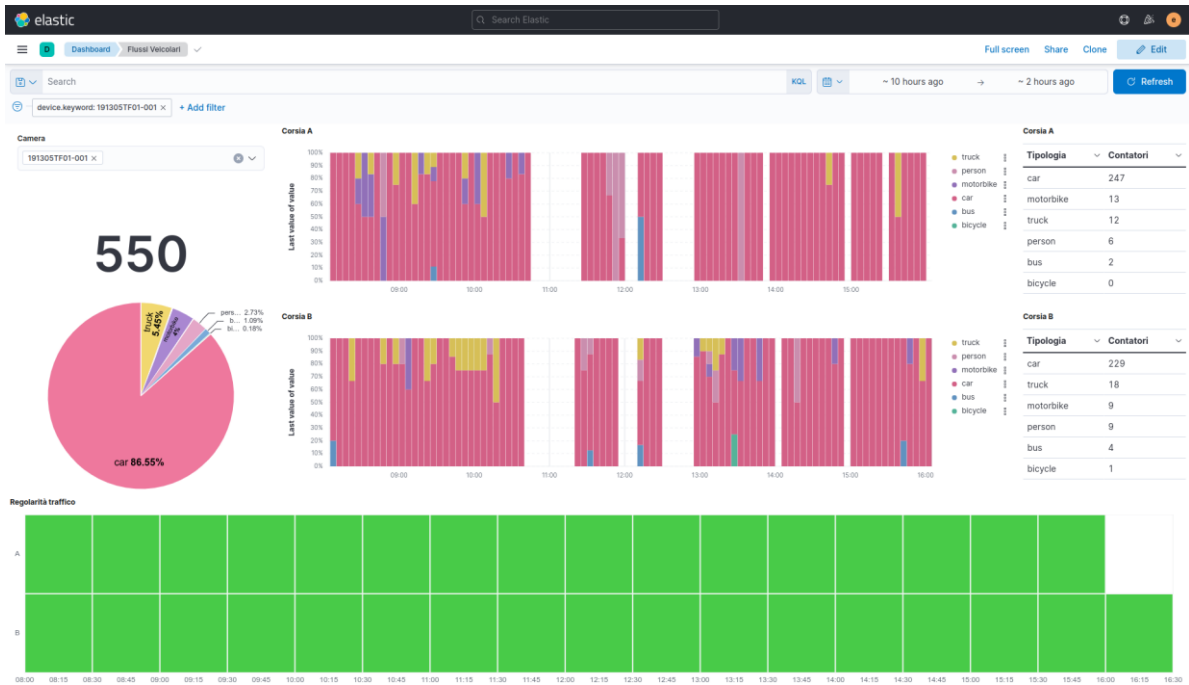
- Improving environmental conditions, public health, and overall urban livability
- Software ecosystem based on Stack4Things® framework and a LoRaWAN infrastructure to monitor weather conditions, air quality, park availability, and traffic flows



LoRaWan coverage



Park finder

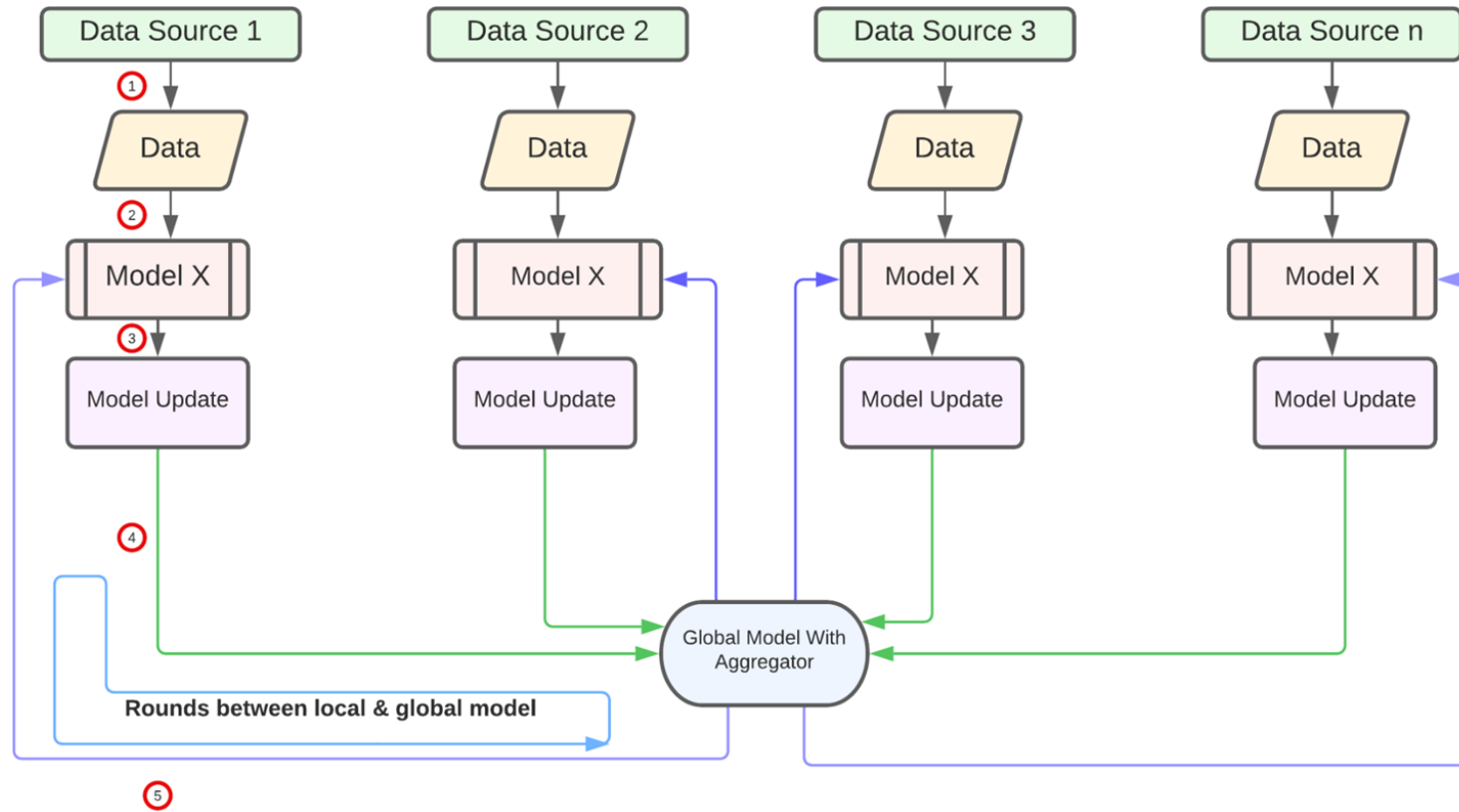


Traffic flow

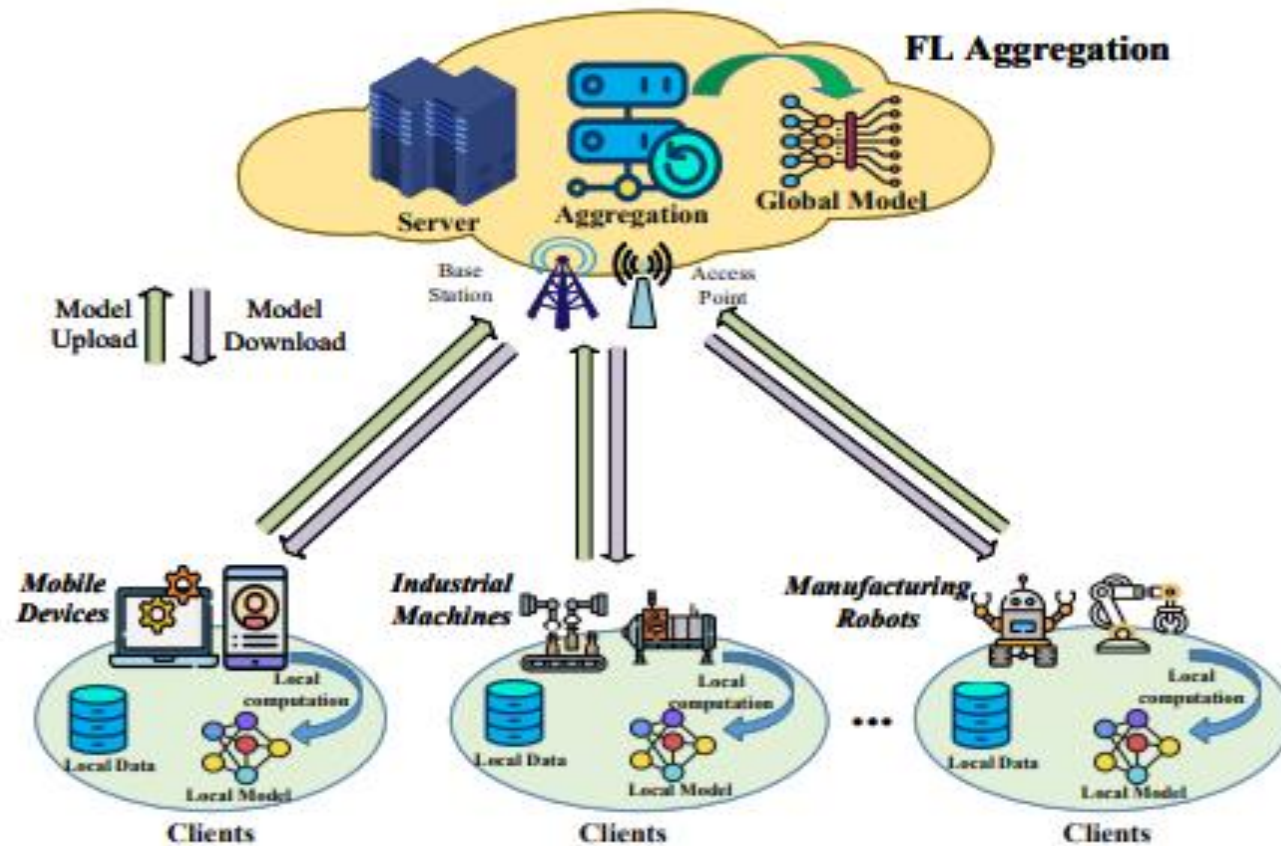


Air quality monitoring

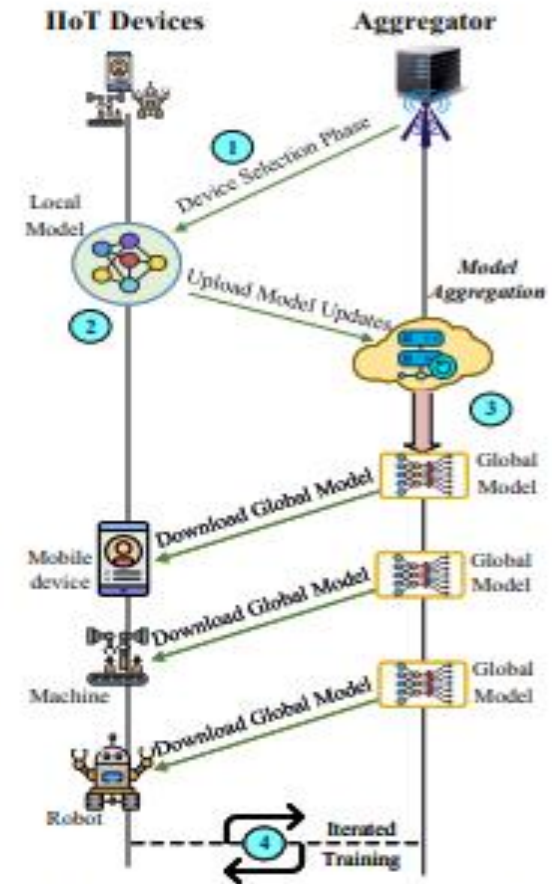
Federated Learning Architecture



Network Architecture and communication process for FL-IIoT



FL-IIoT Architecture



Communication in FL-IIoT

Federated Learning and IIoT: benefits

- **Data Privacy Enhancement:** protecting user information of FL is significant for building sustainable and safe IIoT systems.
- **Improved Learning Quality:** FL attracts large computation and dataset resources from a number of IIoT devices over the distributed IIoT network to train AI models. This cooperation would accelerate the convergence rate of the overall training process and improve learning accuracy.
- **Low-latency Network Communication:** by avoiding the offloading of huge data volumes to the server, FL can significantly reduce communication costs in intelligent IIoT networks, e.g., latency, consumed by raw data transmission
- **Applications to:** financial domain, biometric identification, network security, electric vehicle, smart agriculture

Some Tips to bring home

- **Convergence** of IoT technologies (heterogeneity, interoperability, openness)
- Emergence of **5G and beyond-5G networks**: provision of high-data rates, dense deployments, accurate localization
- **Edge Computing orchestration platforms** for efficient, reliable and secure applications provision
- **Intelligence and automation** in the edge and cloud part through **Machine Learning (ML)** techniques
- Adoption of **Blockchain** to ensure data immutability
- **Internet of Skills** evolution by involving the human in the decision-making loop
- **Reusing** and **best practices** adoption



Recycle/Re-use

THANK YOU FOR YOUR ATTENTION

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Projects links:

- <https://smartme.io>
- <https://arancino.cc>
- <https://git.openstack.org/cgit/openstack/iotronic>

