Software Defined Smart Cities:
Integrating the Cyber World with the Internet of Things

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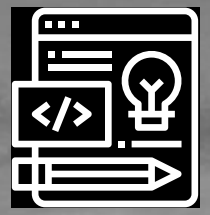
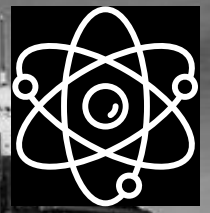
- Coordinator of the International PhD course in Cyber Physical Systems (www.unime.it/it/dottorato/cps)
- Director of the Italian Lab on «Smart Cities & Communities» (https://www.consorzio-cini.it)
- Responsible of the SmartME crowdfunding initiative to exploit Messina into a Smart city (smartme.unime.it)
- Co-founder of SmartMe.io (smartme.io)

WHAT MAKES A SMART CITY



Monitor

Sense/Observe
Communicate/Connect



Model

Analyze/Optimize

Manage

Present/Visualize,
Act

Data collection and analysis to **affect** the system
Act in Real-time @ City Scale
Drive learning algorithms and processing architecture

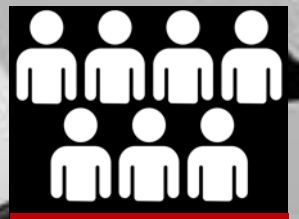
SMART CITIES MEANS DIFFERENT THINGS TO DIFFERENT STAKEHOLDERS

CITIES

- Traffic control
- Air quality monitoring
- Trash management
- Autonomous security systems

BUSINESSES

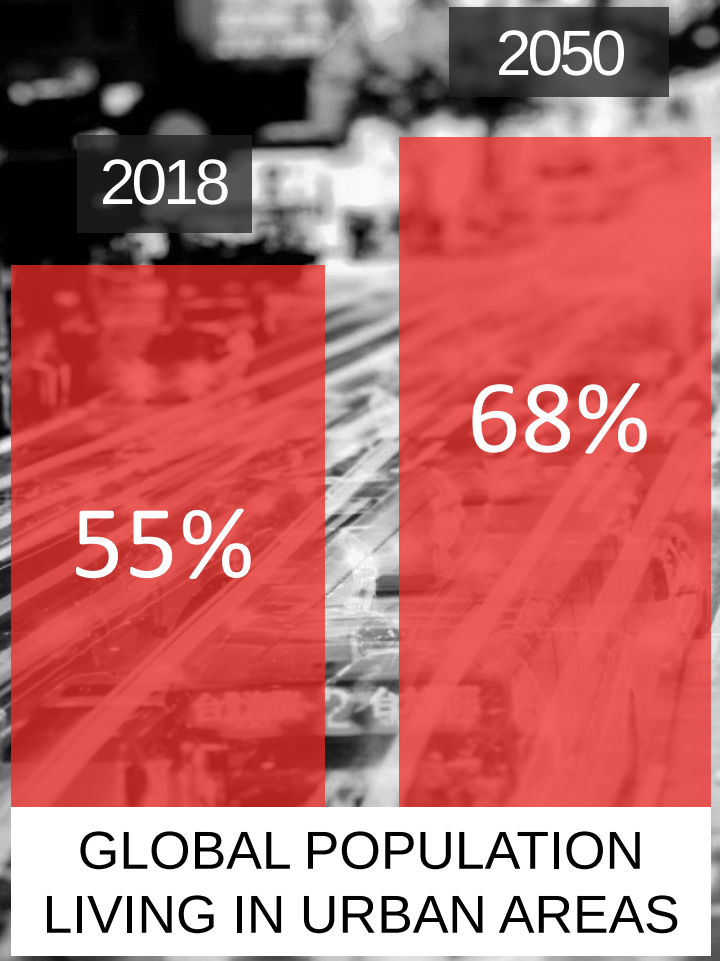
- Use the data being collected
- Driving Innovation
- Providing new services
- Money saving (transportation)



CITIZENS

- Parking solutions
- Real-time traffic jam
- Predict trajects timing
- Connected houses/offices

WHY SMARTER CITIES ARE NEEDED



GLOBAL POPULATION LIVING IN URBAN AREAS

90M MOVE TO URBAN AREAS IN ASEAN BY 2030

255M MOVE TO URBAN AREAS IN CHINA BY 2050

416M MOVE TO URBAN AREAS IN INDIA BY 2050

SMART CITY STRATEGIES

IT'S STILL EARLY DAYS

153 CITIES HAVE PUBLISHED A SMART CITY STRATEGY

15 STRATEGY INCLUDES TARGETS/ACTIVITIES

8 STRATEGY THAT INCLUDES IMPLEMENTATION

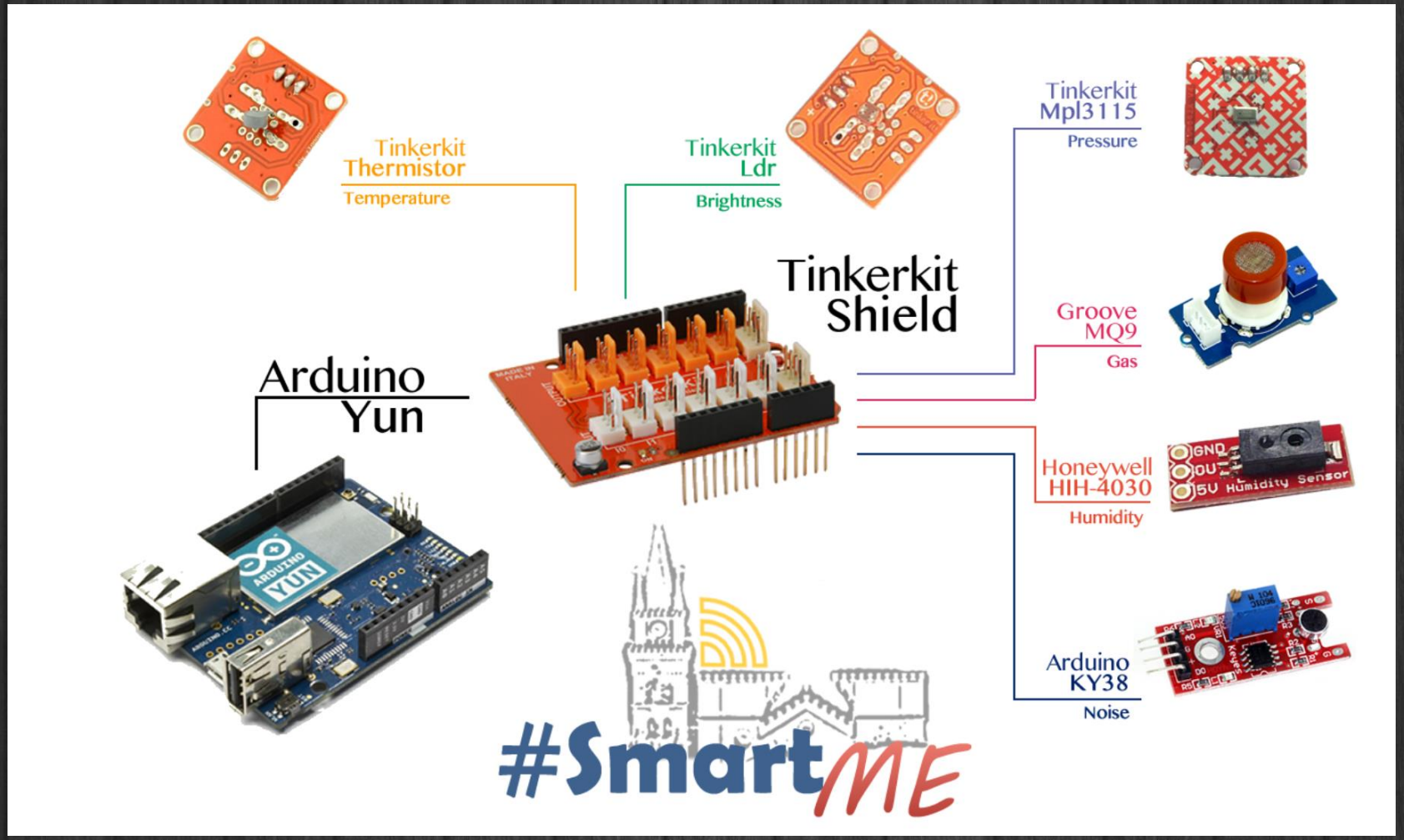
THE SMART CITY CHALLENGE


TAKEAWAY
TECHNOLOGY IS NOT THE GREATEST CHALLENGE, WE ARE
YOU CAN'T DO IT ALONE…
COLLABORATE OR DIE

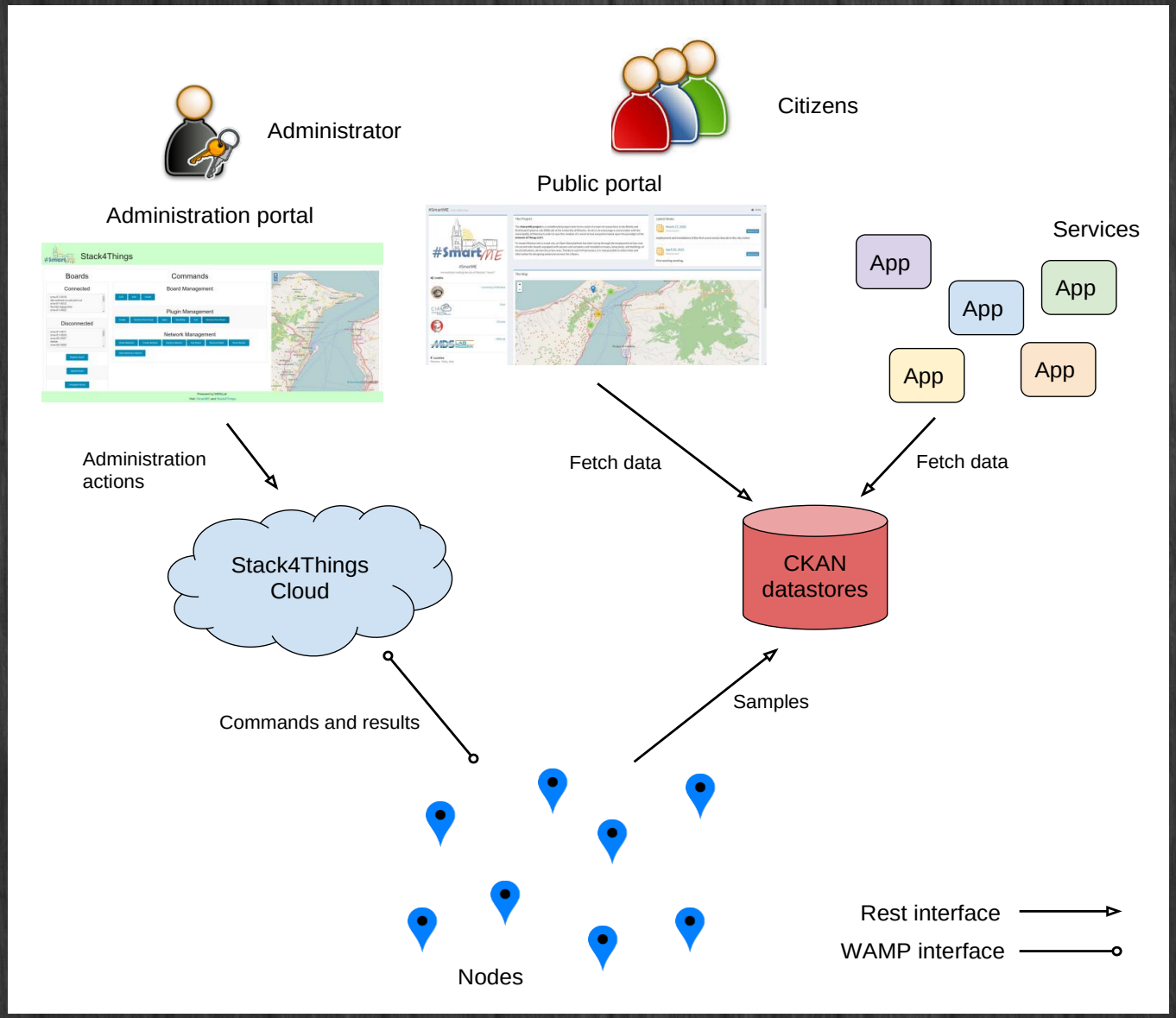
#SmartME CROWDFUNDING INITIATIVE OF UNIVERSITY OF MESSINA

#SmartME intends to exploit the most innovative technology to contribute to a “smart” development process that fosters new behaviour and attidute towards social wellness, thus improving services and quality of life.

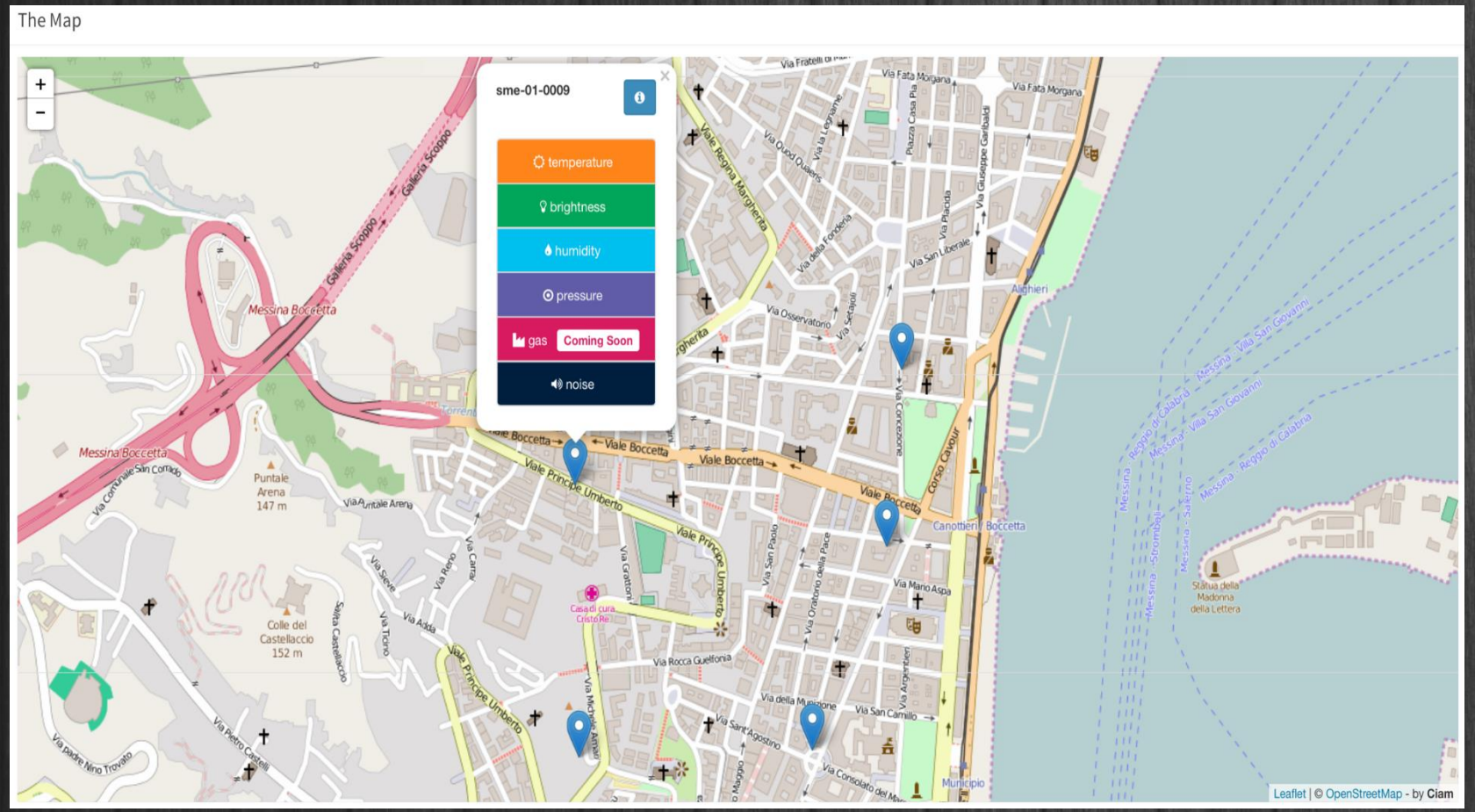
#SmartME EXAMPLE OF AN IOT DEVICE



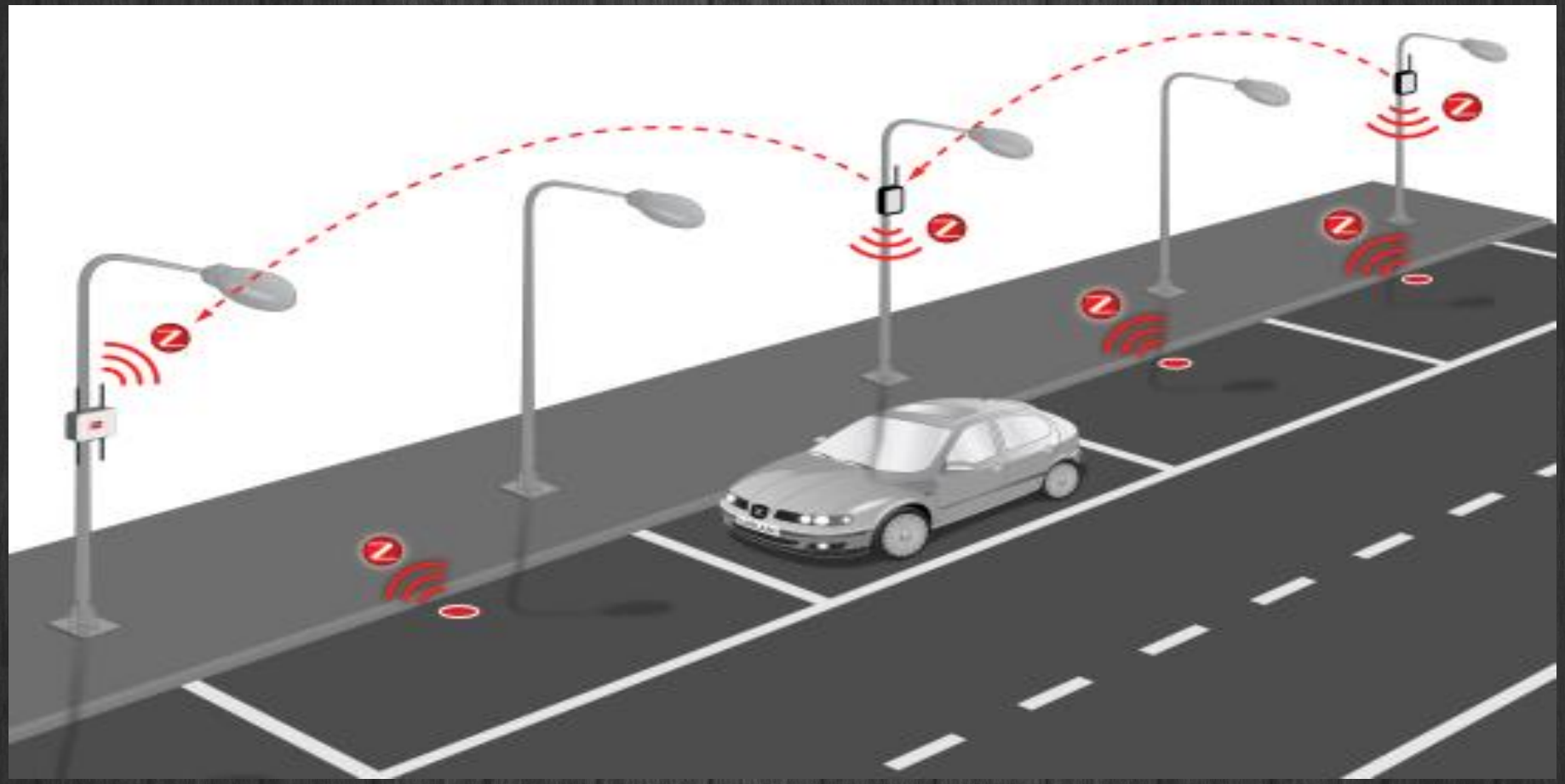
#SmartME ARCHITECTURE OF #SMARTME FRAMEWORK



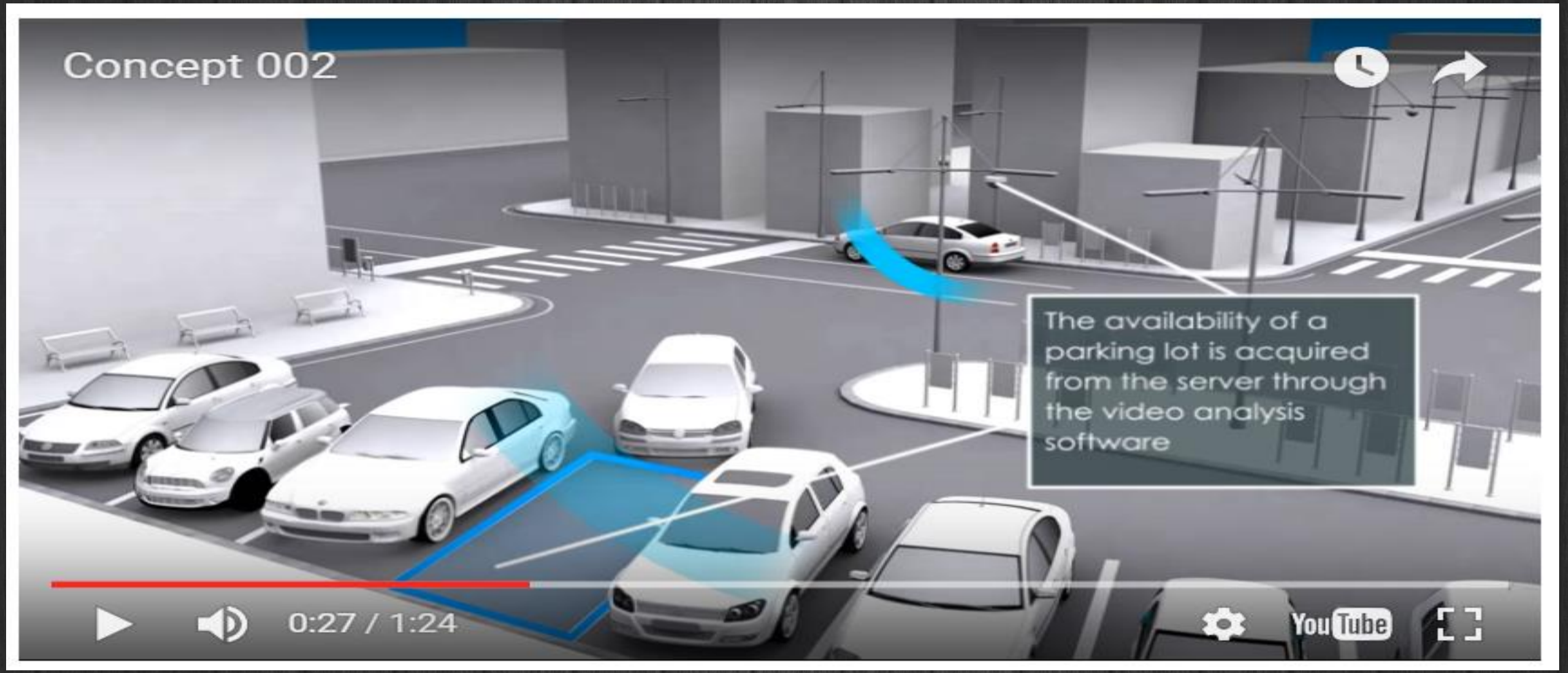
#SmartME services ENVIRONEMENTAL MONITORING



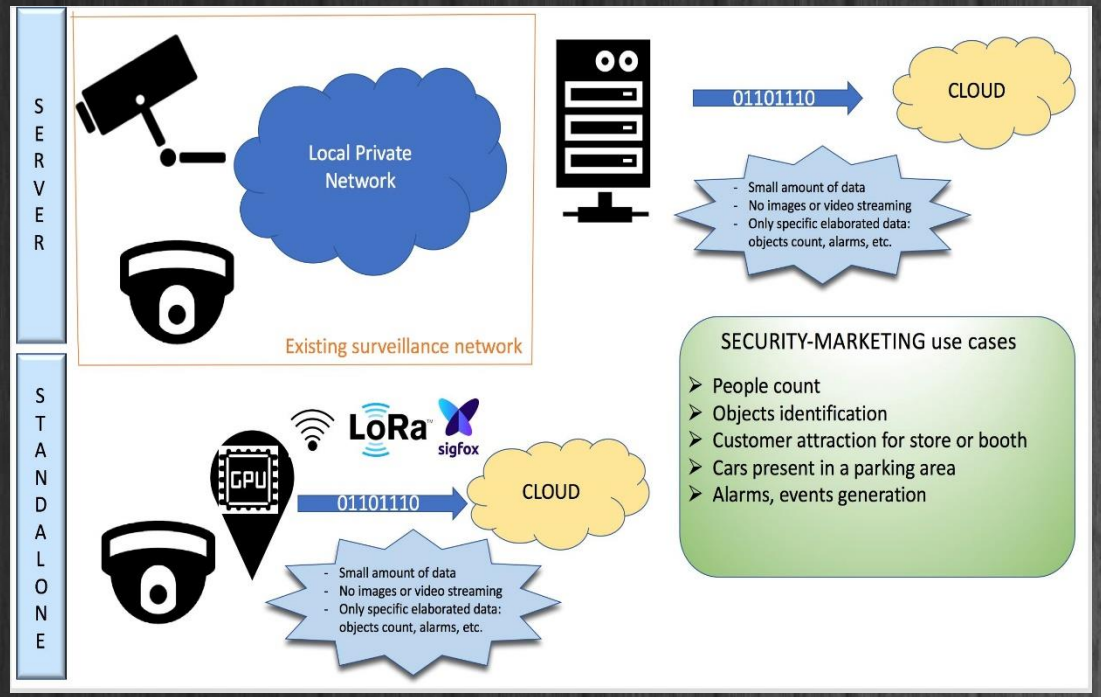
#SmartME services SMART PARKING 1/2



#SmartME services SMART PARKING 2/2



#SmartME services OBJECTS IDENTIFICATION/COUNTING



The Object Counter is an intelligent device, therefore “smart”, which uses mathematical-computer computation models (neural networks) based on the functioning of biological neural networks.

How does it work?

It works "On the Edge": all the processing takes place on the smart device and no image is recorded or transferred.

#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.

DEMO

slices RI

Our Mission Community Offering Projects Our News

what is Slices-RI?

SLICES is a flexible platform designed to support large-scale, experimental research focused on networking protocols, radio technologies, services, data collection, parallel and distributed computing and in particular cloud and edge-based computing architectures and services.

learn about us

who we are

SLICES consortium gathers partners from 15 European countries, all of them having committed to contribute resources and has received the endorsements of key stakeholders and the political supports of 11 European Governments. Several of the current partners are operating facilities that are already on their national and regional RI roadmaps. It is the case for instance for France, Greece, Poland and Norway. The numerous letters of support testify the strong support from the community as well as from industry and member states. SLICES will encourage and foster all the initiatives

Italian Node:
CNR, CINI, CNIT

Virtual Workshop on March 3-4, 2021
http://slices-ri.eu/index.php/events/virtual-workshop-on-march-3-4-2021/

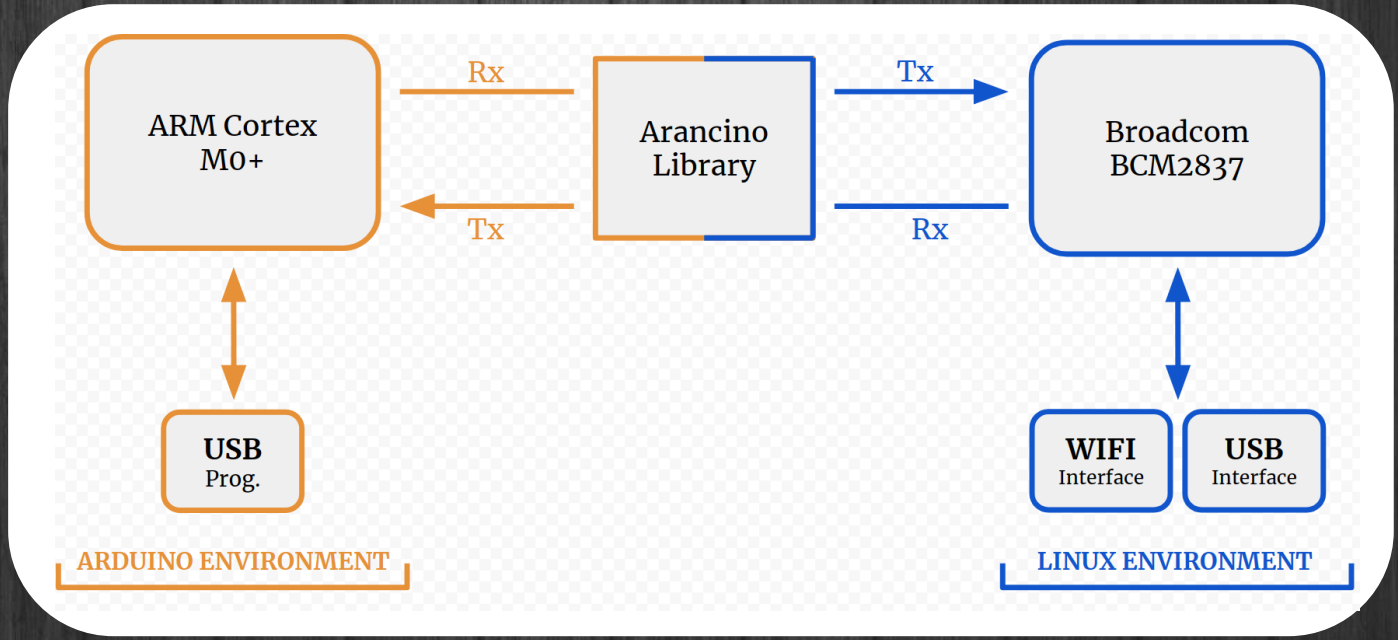
smartme.IO

- *smartme.IO* is an academic spin-off company of the University of Messina.
- Designs and implements products combining open source and low-cost IoT technologies with OpenStack-based Cloud technologies.
- Provides best-in-class solutions for Metering, Devices and Fleet Management, Monitoring, Crowdsensing and other aspects related to Smart Environments
- The solutions addresses the requirements of municipalities, utilities, companies operating in challenging environments, such as airports and stations, interested in identification facilities, traceability, safety and video surveillance

Projects

SmartMe.IO ARANCINO SMART BOARDS

arancino.cc



Stack4Things MOTIVATION

How to manage in a scalable and powerful way the proliferation of (increasingly smarter) mobile and IoT devices?

IoT ecosystem

- Mobiles
- Cyber Physical Systems
- Smart appliances
- Sensors/Actuators
- Wearables
- Vehicles ...

Stack4Things CLOUD AND IOT INTEGRATION

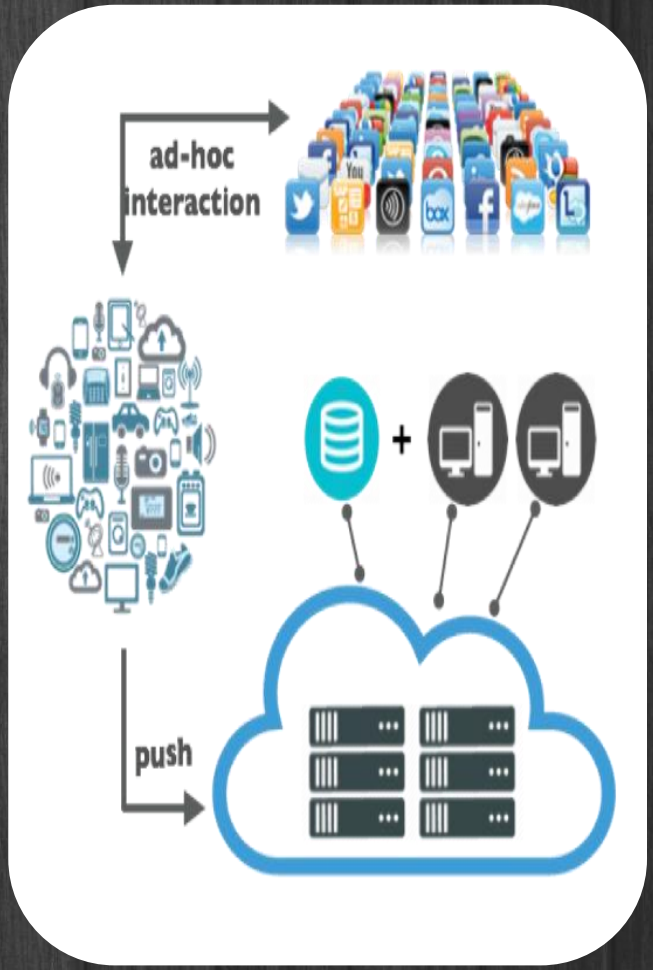
Data-oriented approach

- 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)

Application-specific (vertical) approach

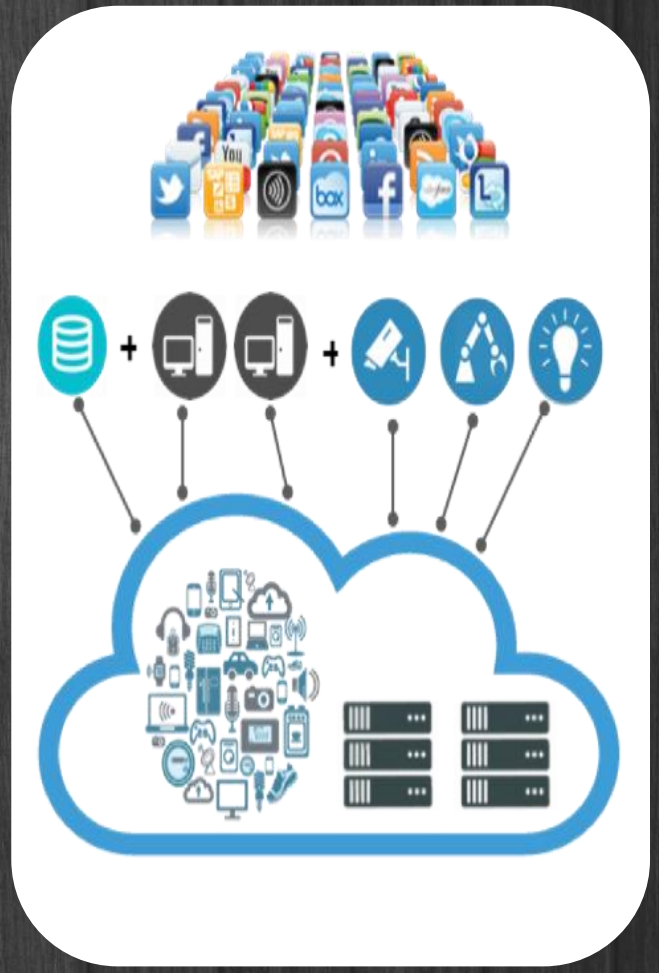
- The application uses ad-hoc mechanisms to interact with IoT devices.
- No explicit interactions between Cloud components and IoT infrastructure.
- Static infrastructure deployment.



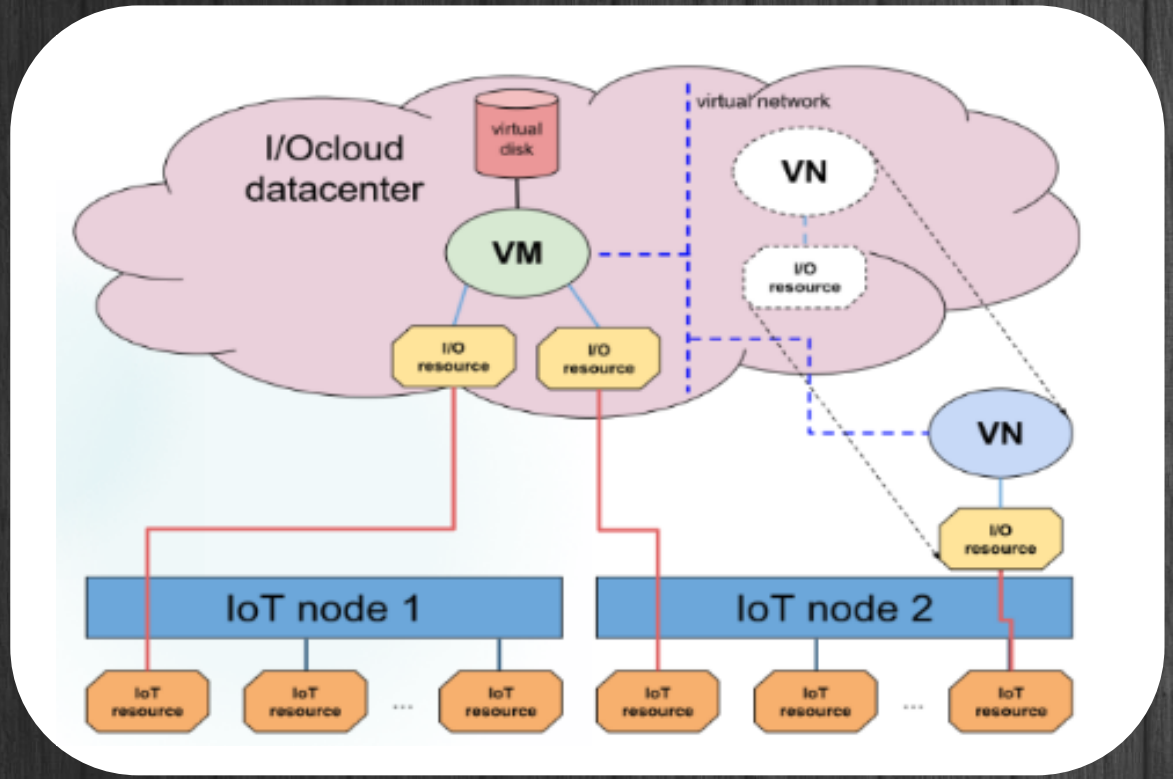
Stack4Things IoT FULL CLOUDIFICATION (I/OCLOUD APPROACH)

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



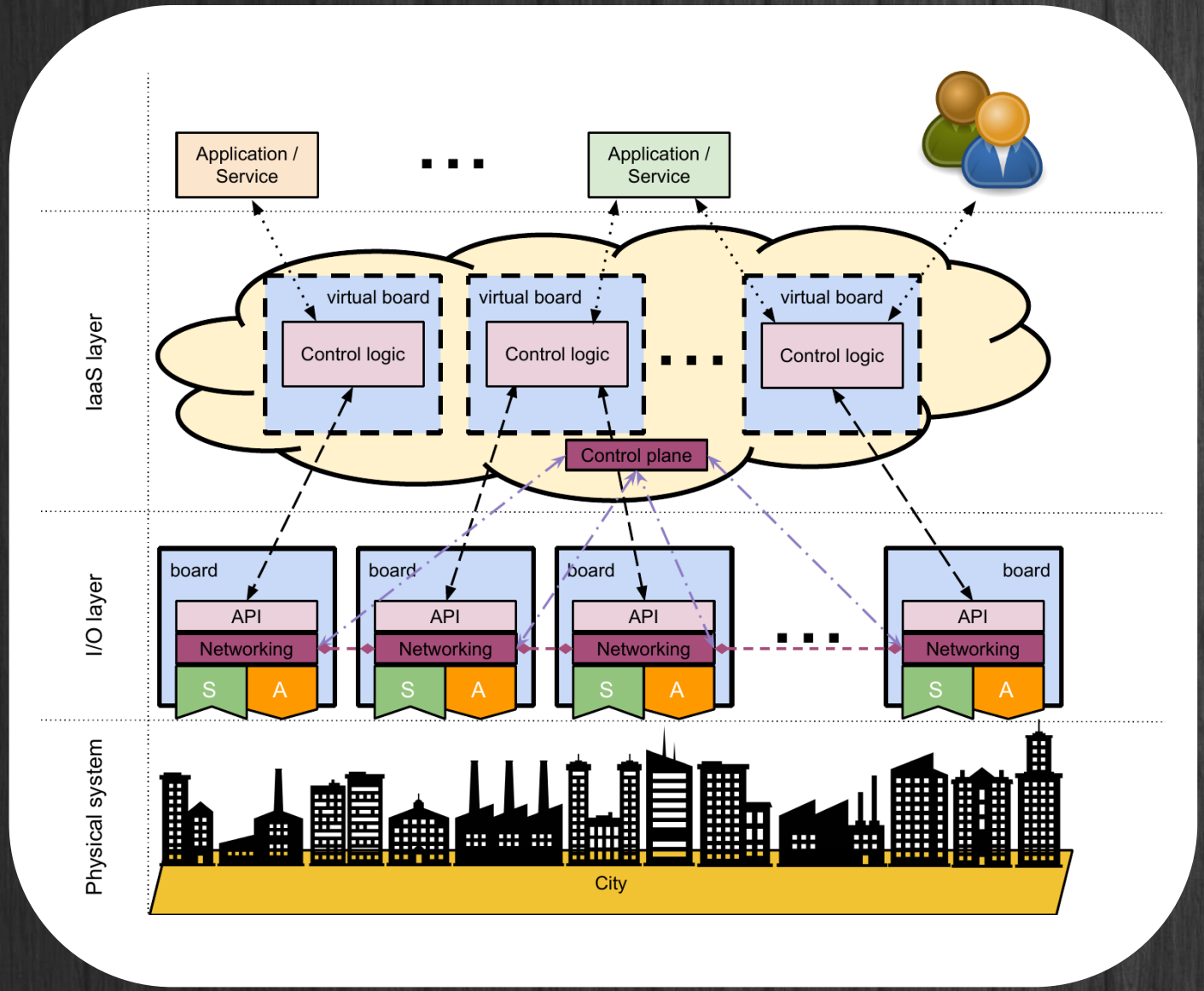
Stack4Things IoT FULL CLOUDIFICATION (I/OCLOUD APPROACH)



Approaches
(to I/O extensions for the Cloud)

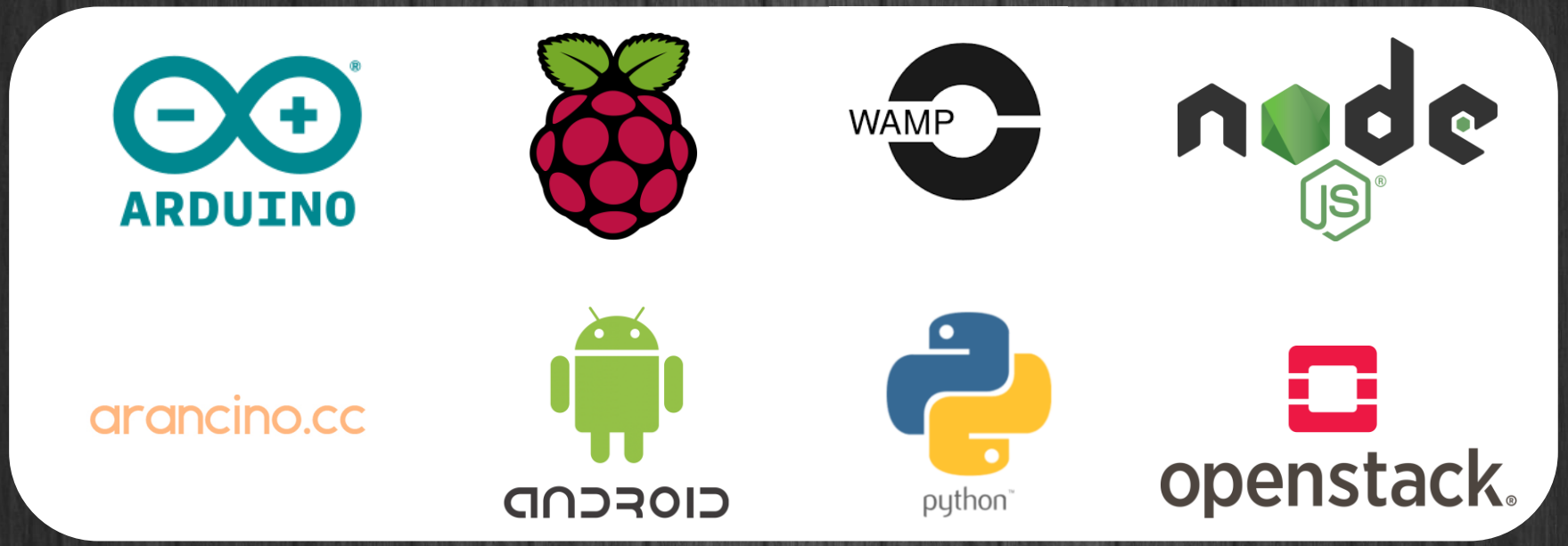
- Bare-metal (VMs with I/O)
- Virtualization (VNs) through Containers

Stack4Things SOFTWARE DEFINED CITY



- Analogy with Software Defined Networking (SDN).
- Extends the SD* approach to a cyber city system to enable the re-configuration of the undelying infrastructure.
- Several controllers exploit and implement the requested node topologies through generalized rules and according to predefined policies.

Stack4Things TECHNOLOGY ENABLERS

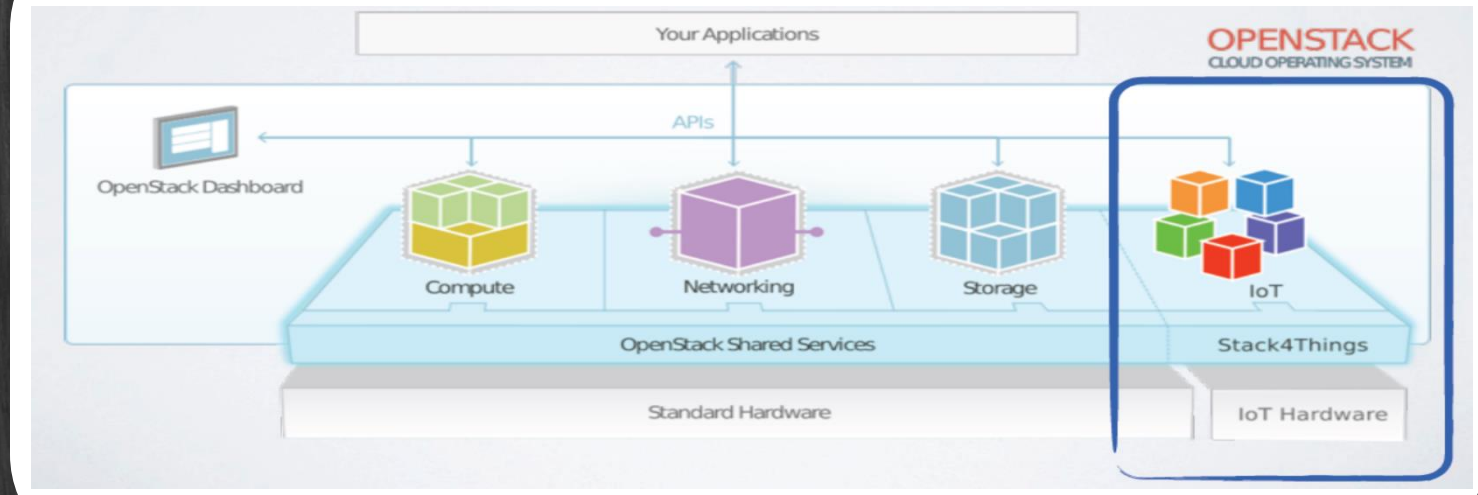


Stack4Things S4T & OPENSTACK

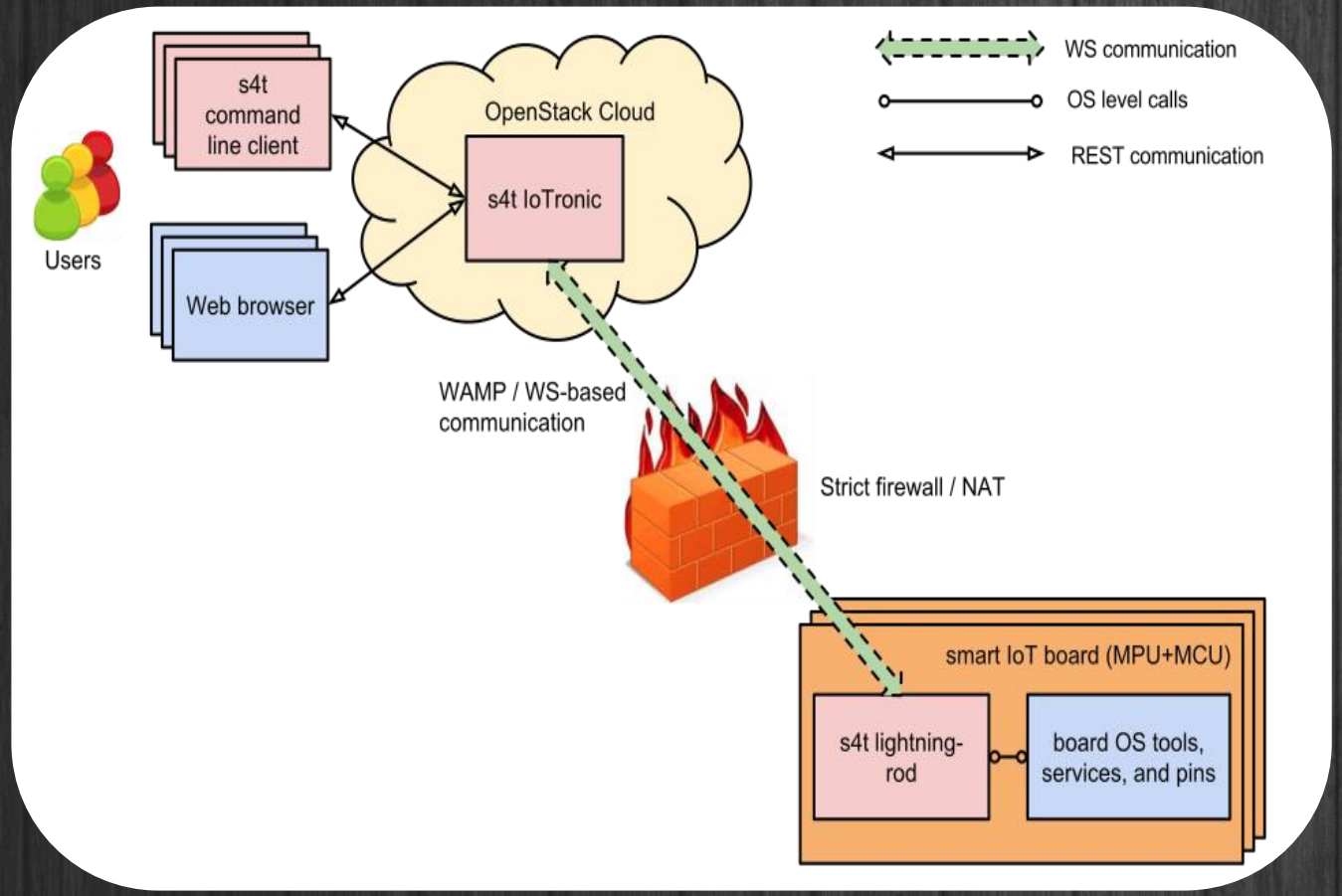
IoT resource management service for OpenStack Clouds

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

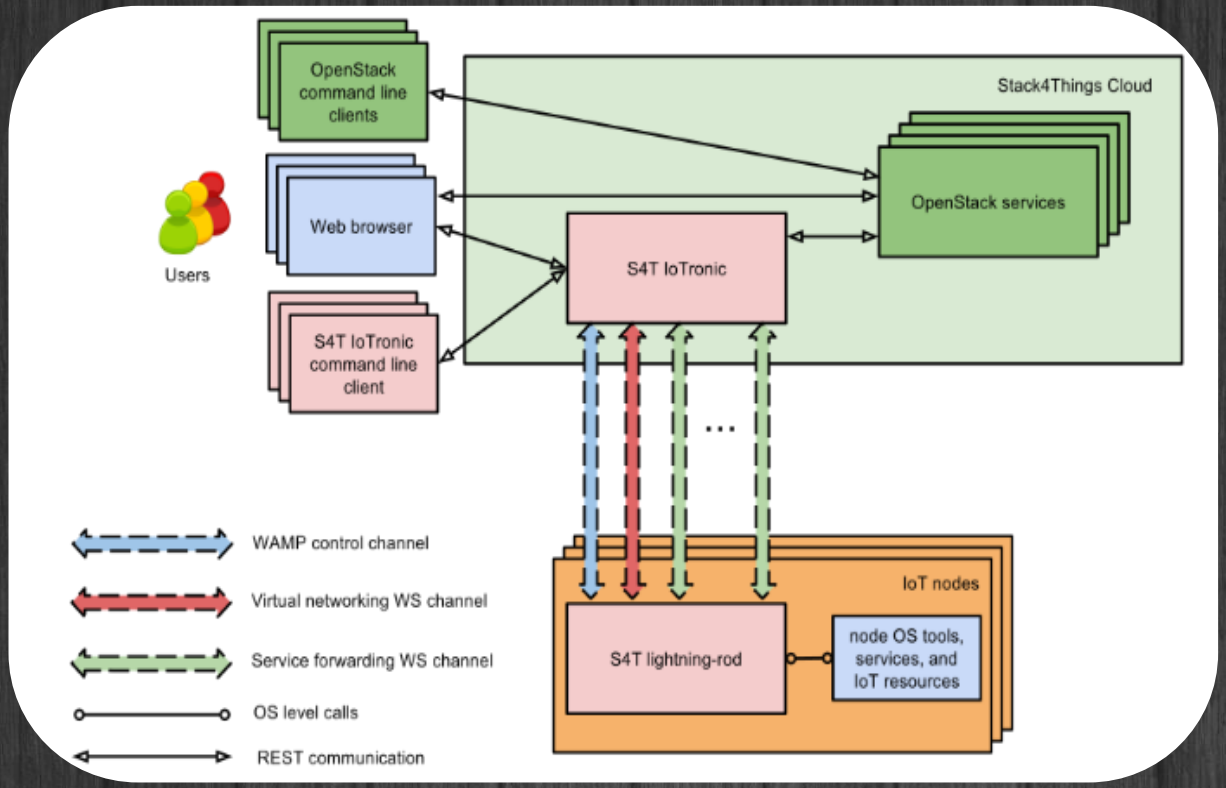


Stack4Things HIGH-LEVEL OVERVIEW



- 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 mechanims to overwhelm the unique constraints of IoT deployments

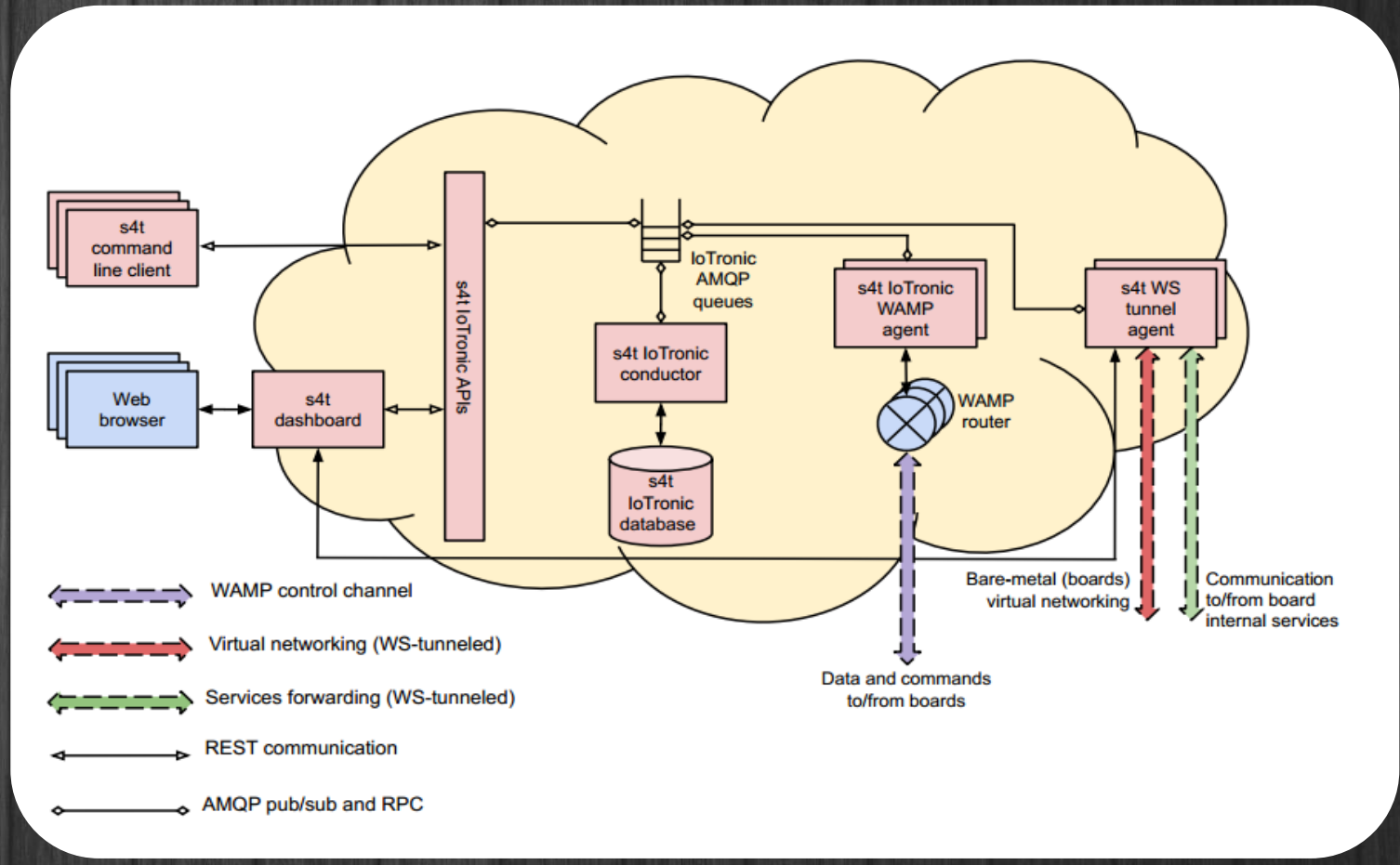
Stack4Things HIGH-LEVEL OVERVIEW



- Use of a software probe on the device-side (lightning-rod)
- OpenStack compliant service (IoTronic)
- Use of WAMP and plain WebSocket control channels
- REST interfaces

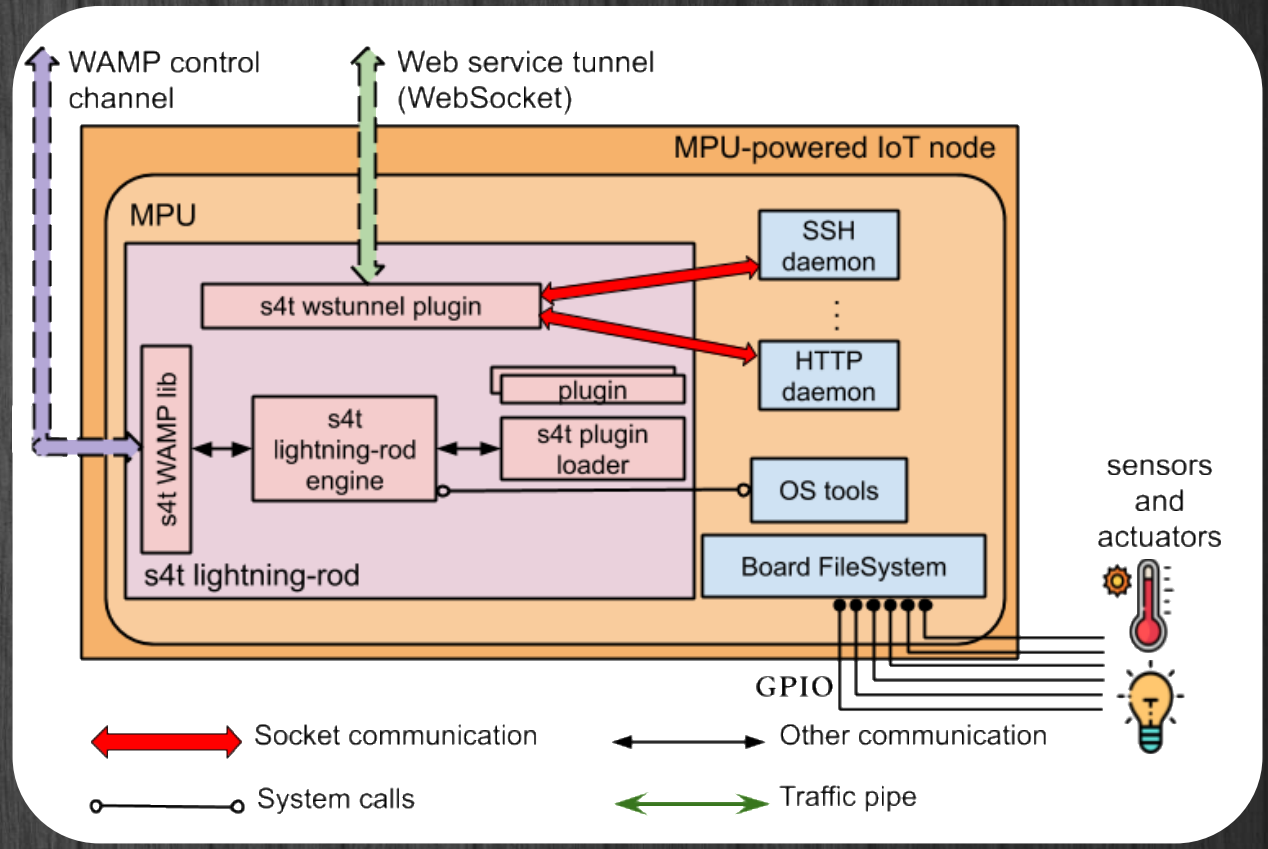
Stack4Things CLOUD-SIDE ARCHITECTURE

- 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.



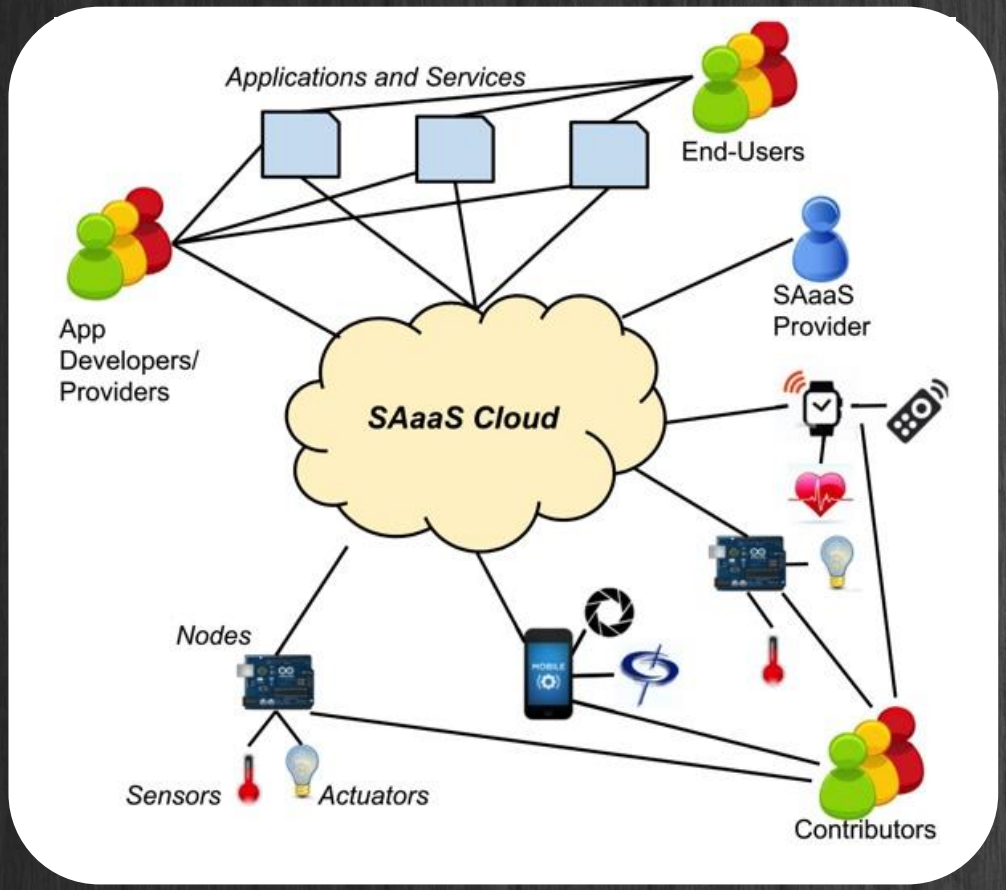
Stack4Things BOARD-SIDE ARCHITECTURE

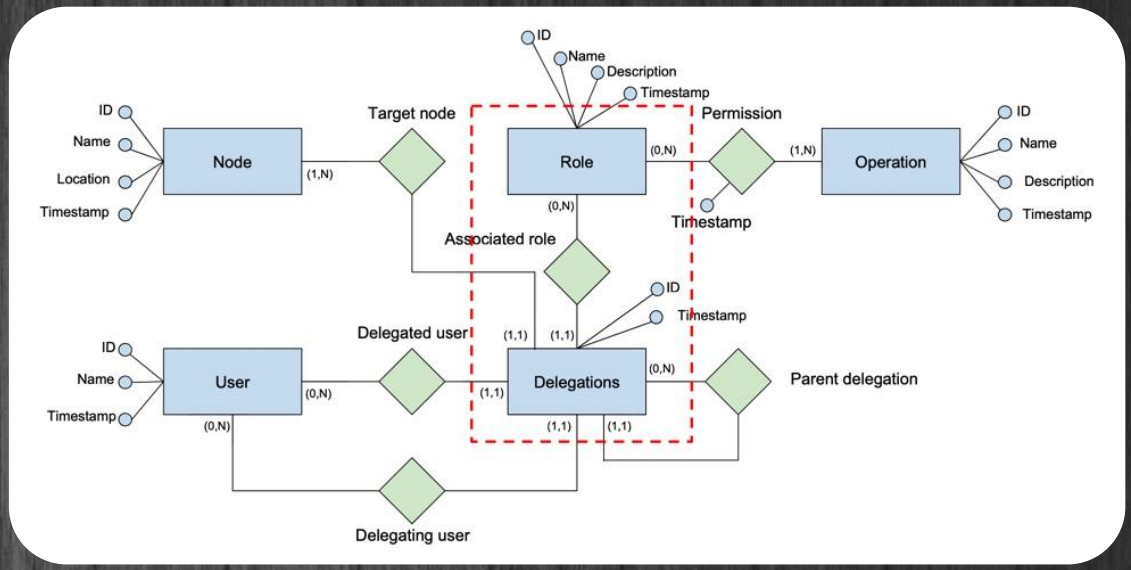
- The Lightning-Rod engine is the core of the device-side software architecture.
- The engine interacts with the Cloud through WAMP protocol (i.e., pub/sub and RPCs)
- The WebSocket libraries allows the engine to act as a WebSocket reverse tunnelling server.
- Custom plugins can be injected from the 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.

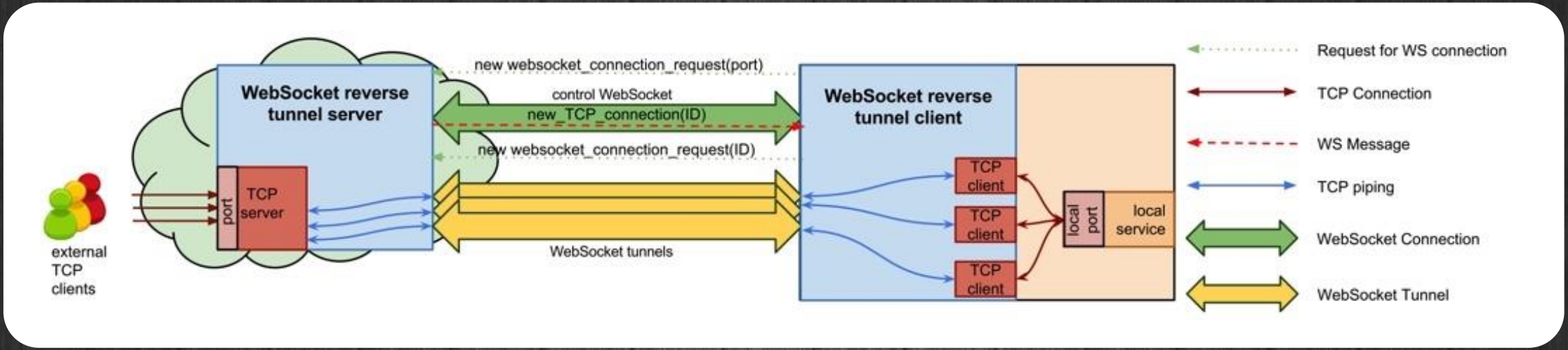
Stack4Things SENSING-AND-ACTUATION-AS-A-SERVICE (SAaaS)





- Management of different entities involved (owners, administrators, users ...)
- OpenStack Keystone Identity service is used to manage authorizations and delegation.
- Blockchain is being used to enhance authorization/delegation processes.

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:

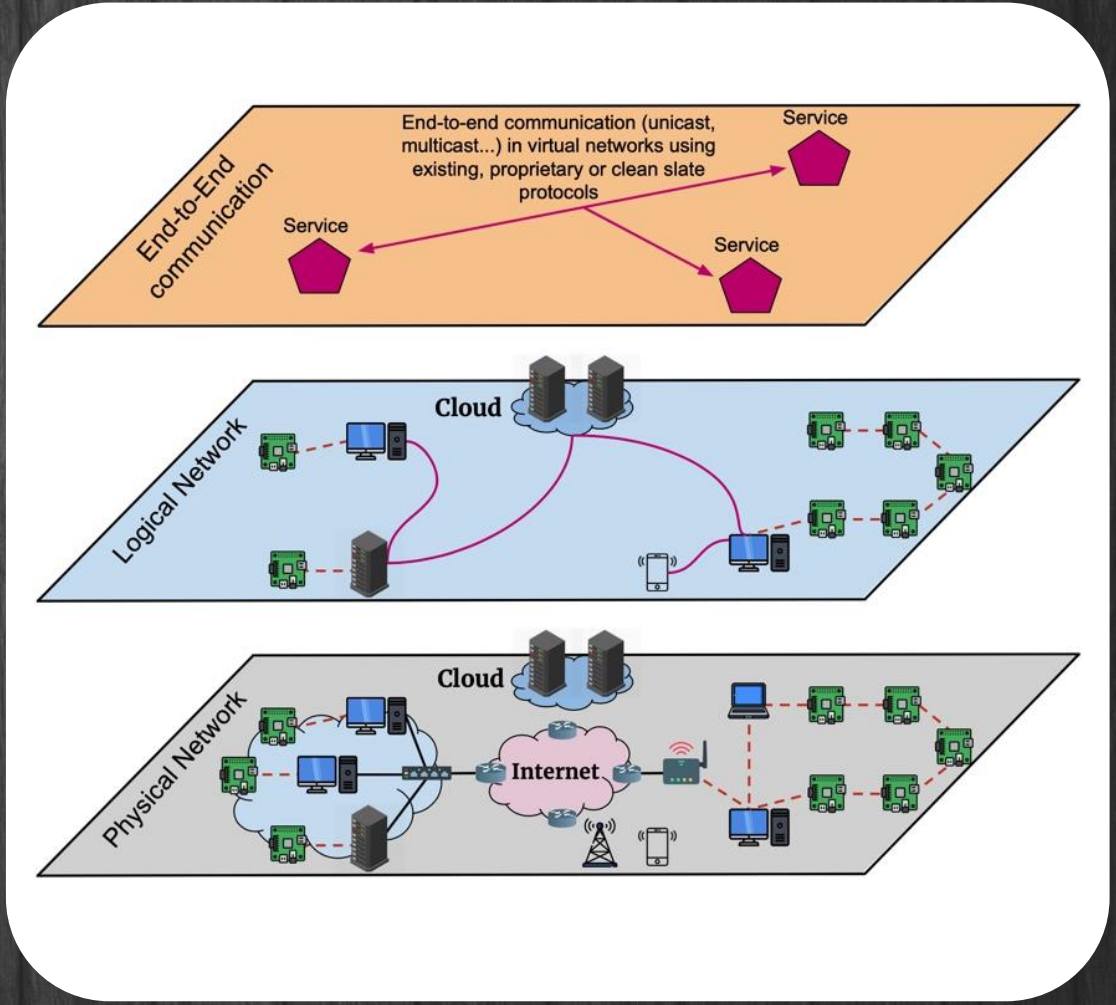
An SSH daemon running on the board (i.e., port 22) can be exposed through the public IP address of the Cloud and a specific port.

Stack4Things LOGIC CUSTOMIZATION: PLUGINS

- Adapt the behaviour, or define the business logic of remote devices.
- Users can inject custom code on any device at runtime under the guise of independent pluggable modules.
- Plugins are managed/stored on the Cloud.
- Stack4Things provides Node.js and Python as runtime environments.
- Two kinds of plugins are available in the system: **synchronous** and **asynchronous**.
    - **Synchronous plugins:** are characterized by a short execution time and can provide a result to the user (in the form of a JSON object).
    - **Asynchronous plugins:** are long-running pieces of code that can be executed on a node and do not provide any result.

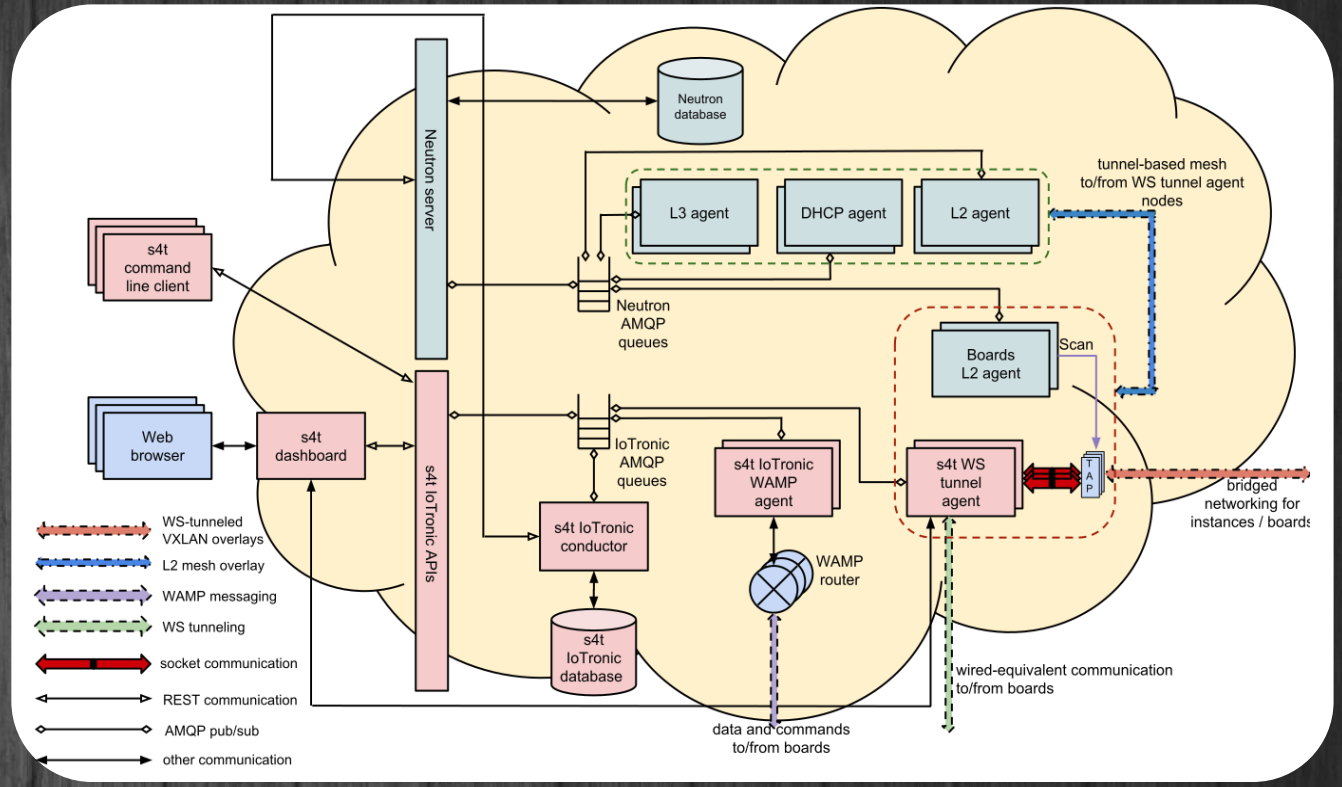
Stack4Things VIRTUAL NETWORKING IN IOT

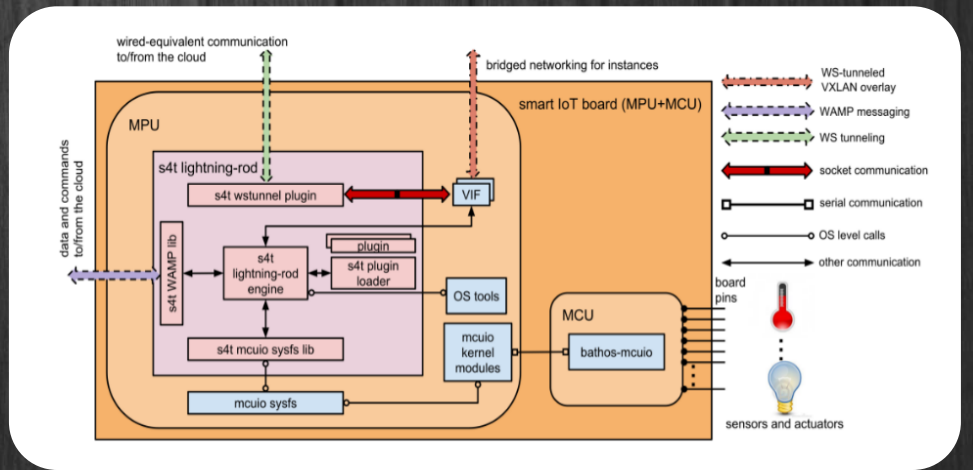
- Virtualization both at the network and datalink layers enables flexible overlay networking topologies.
- Infrastructure-agnostic applications.
- Enable the creation of network overlays between geographically dispersed devices, we integrated Neutron, the networking subsystem of OpenStack, with our S4T 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.



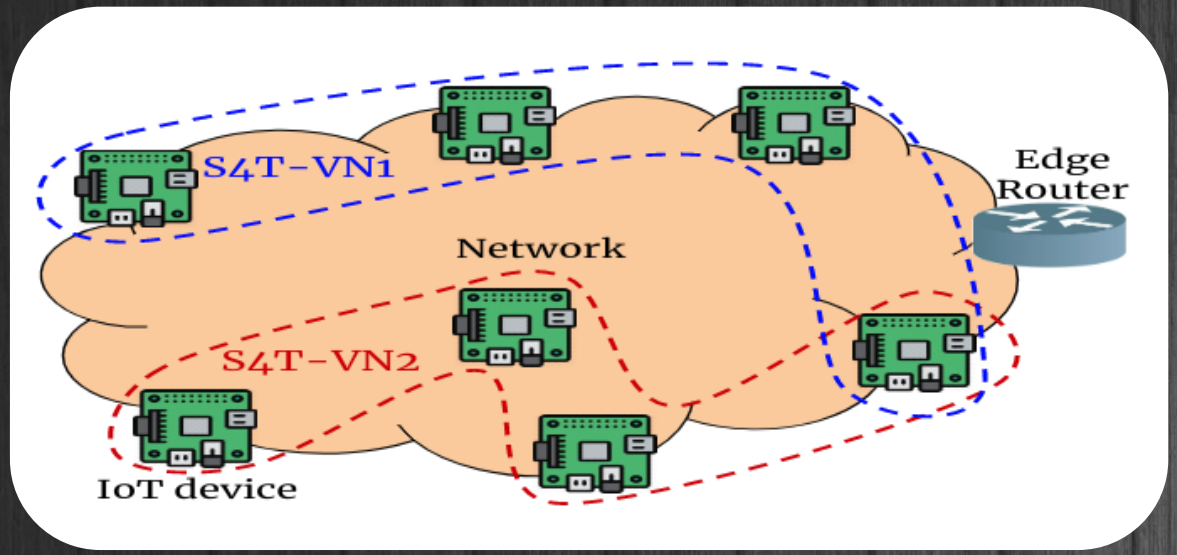
Stack4Things VIRTUAL NETWORKING IN IOT

- 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.

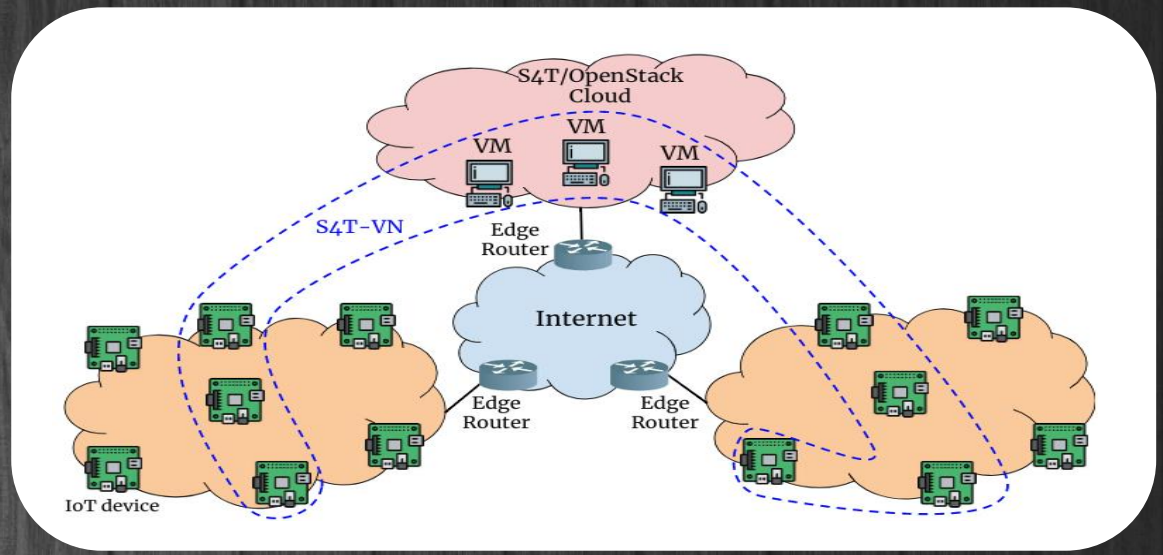




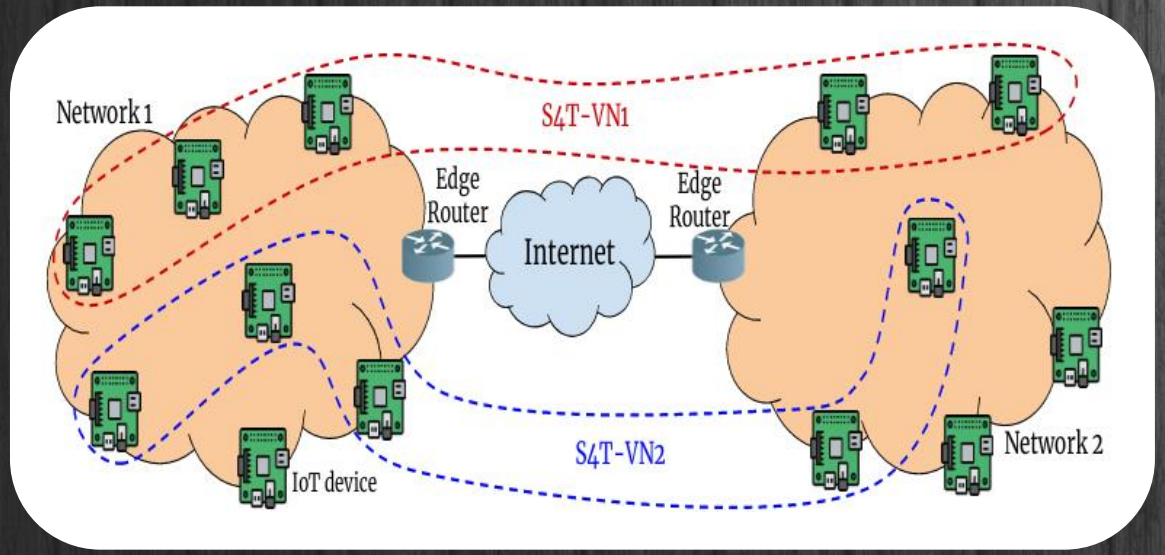
Stack4Things VIRTUAL NETWORKING IN IOT



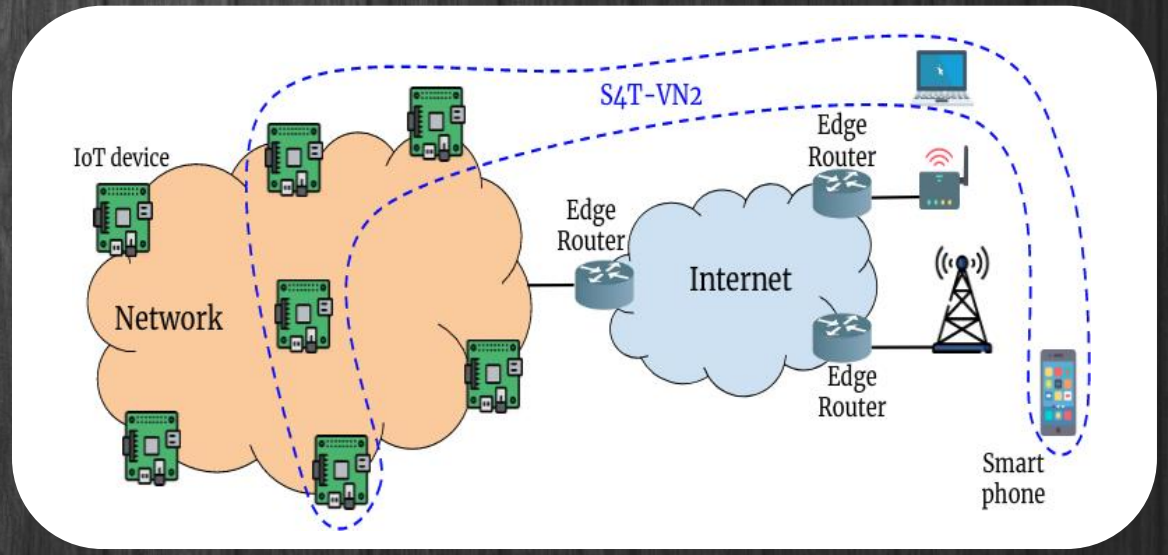
USE CASE 1



USE CASE 3



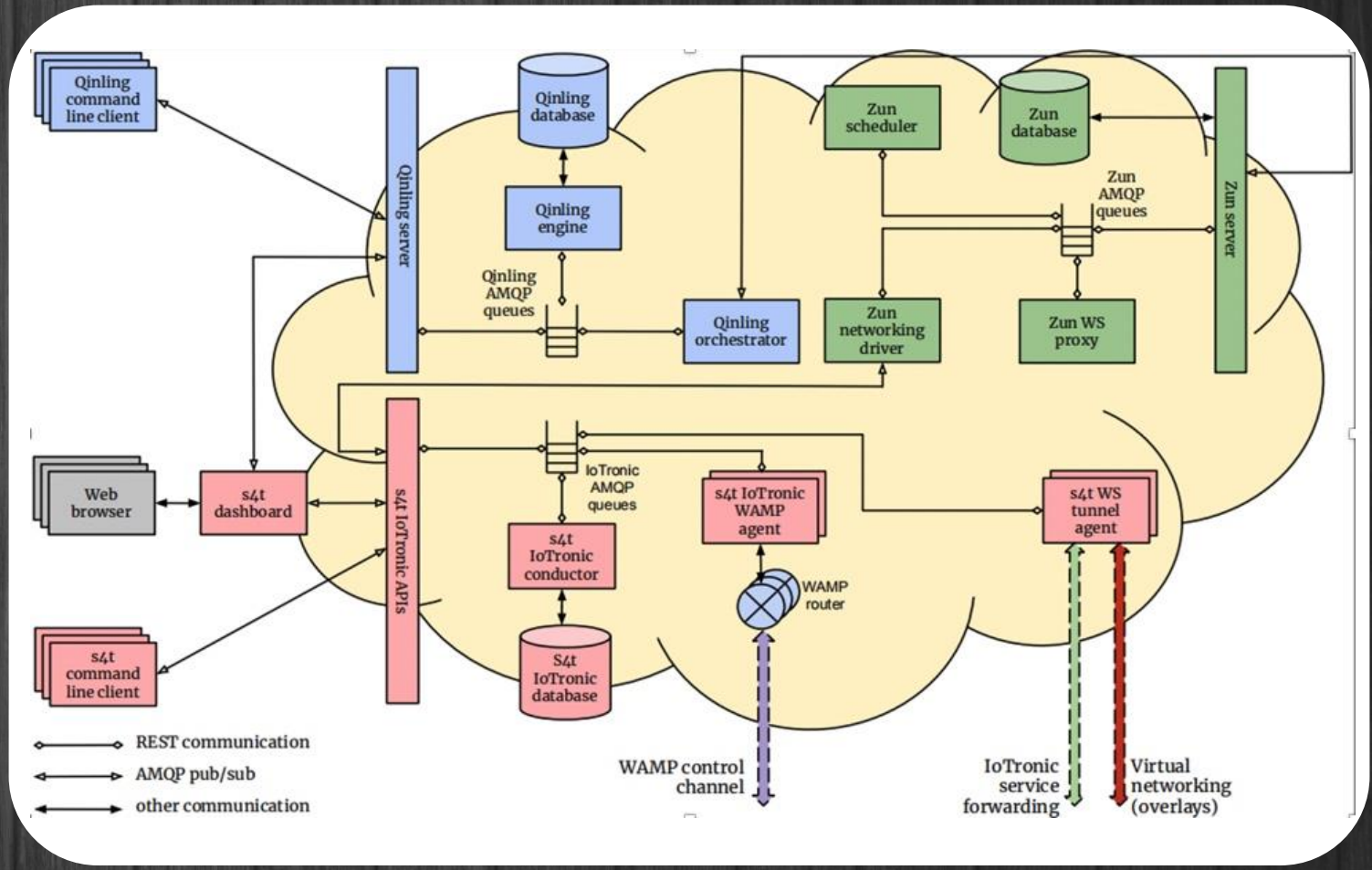
USE CASE 2



USE CASE 4

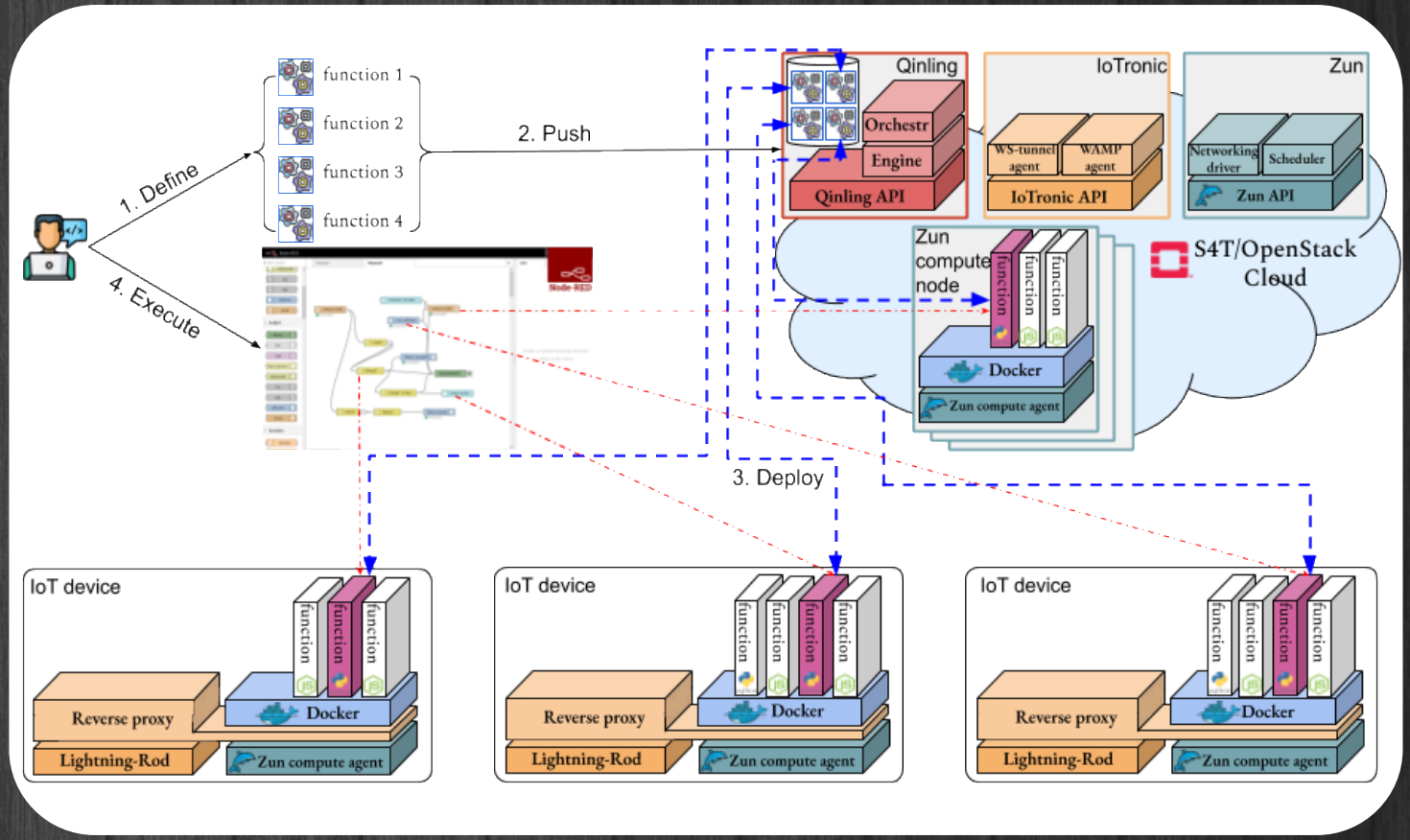
Stack4Things EDGE FUNCTION-AS-A-SERVICE (FaaS)

- 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.

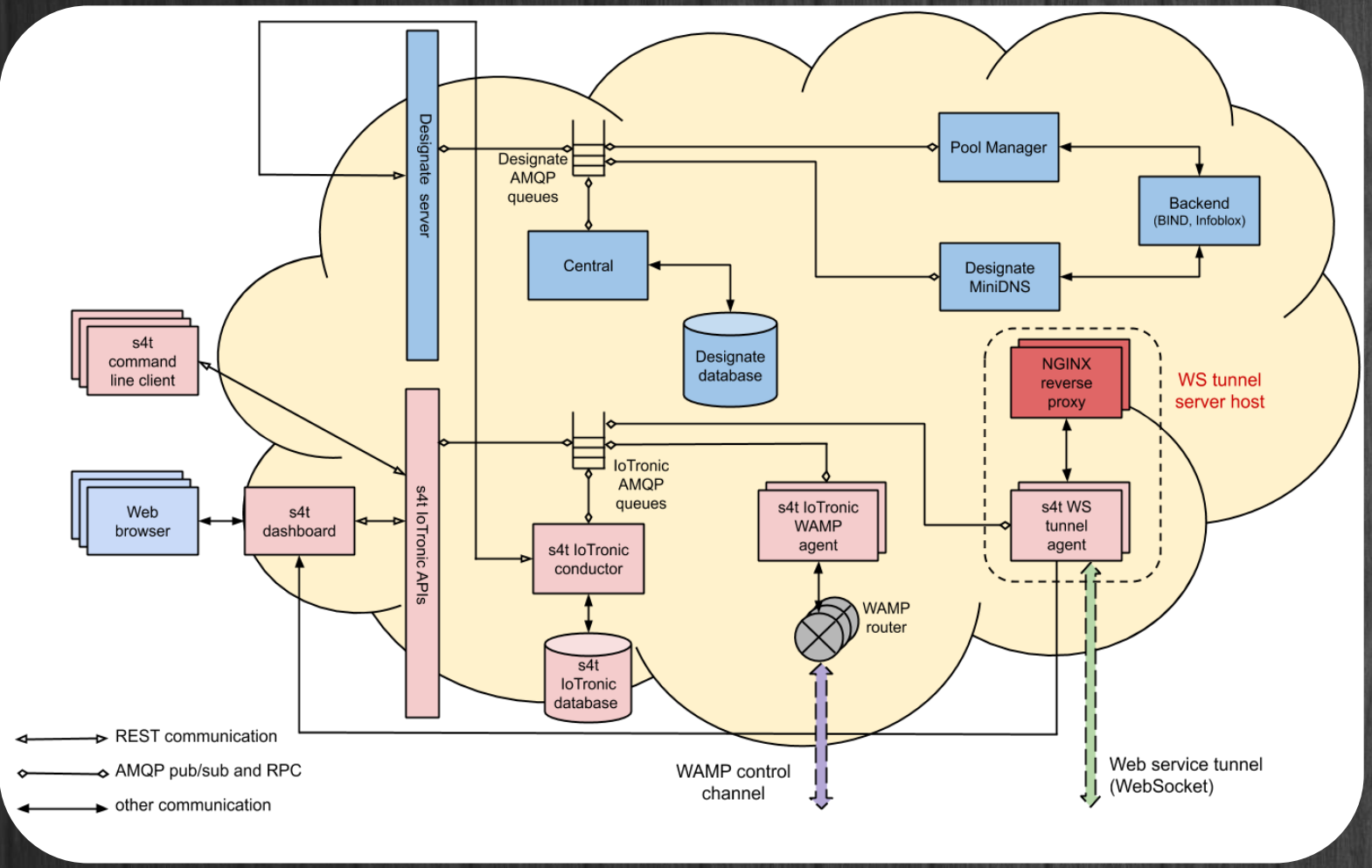


Stack4Things EDGE FUNCTION-AS-A-SERVICE (FaaS)

- 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).

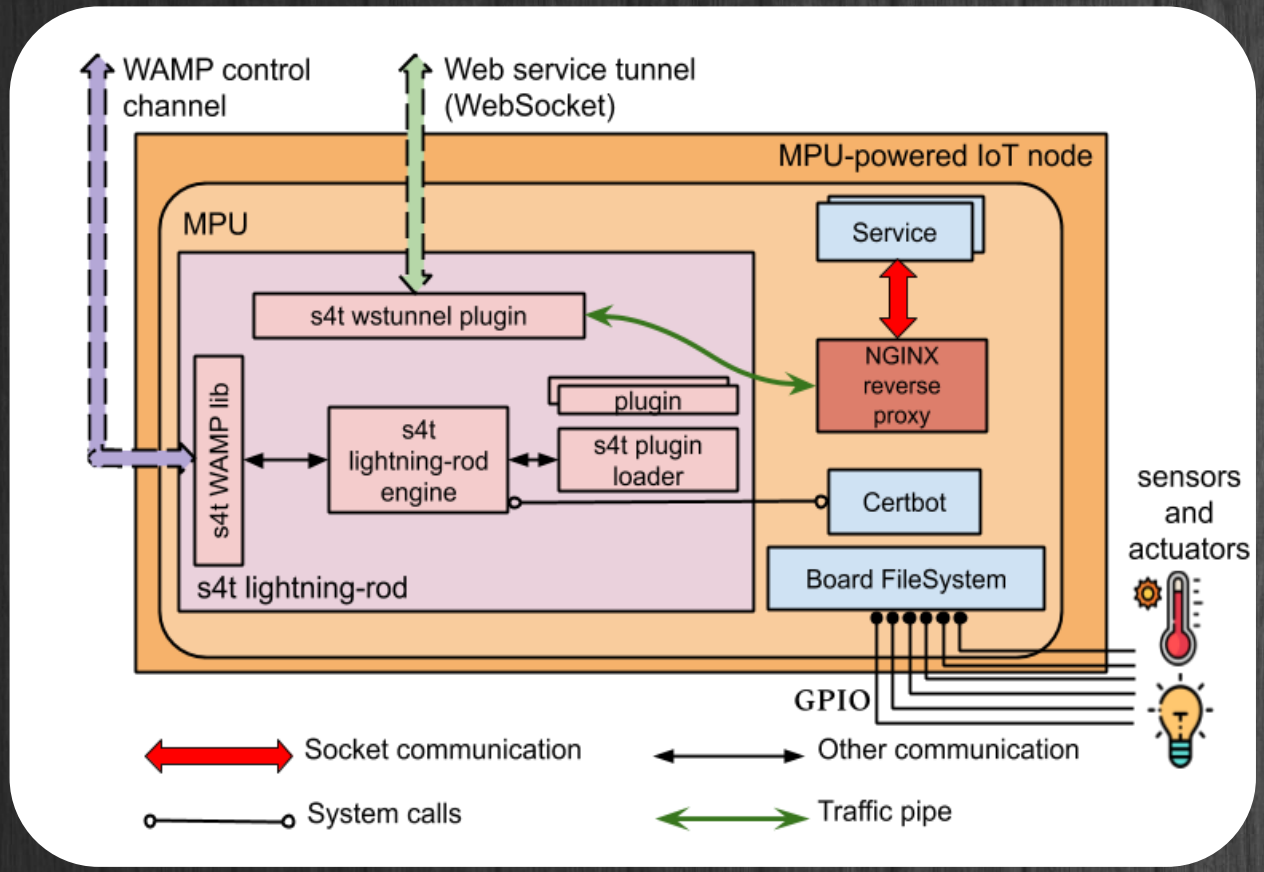


Stack4Things WEB OF THINGS



- Integration of the OpenStack DNS-as-a-Service, Designate, with IoTronic.
- Adding new devices or removing others from the deployments is efficiently managed.
- Manage/associate unique URLs with services running on IoT devices.
- Websockets tunnels are used to send the requests received.
- The NGINX reverse proxy is used to forward received request to their destination based on the URLs indicated.

Stack4Things WEB OF THINGS

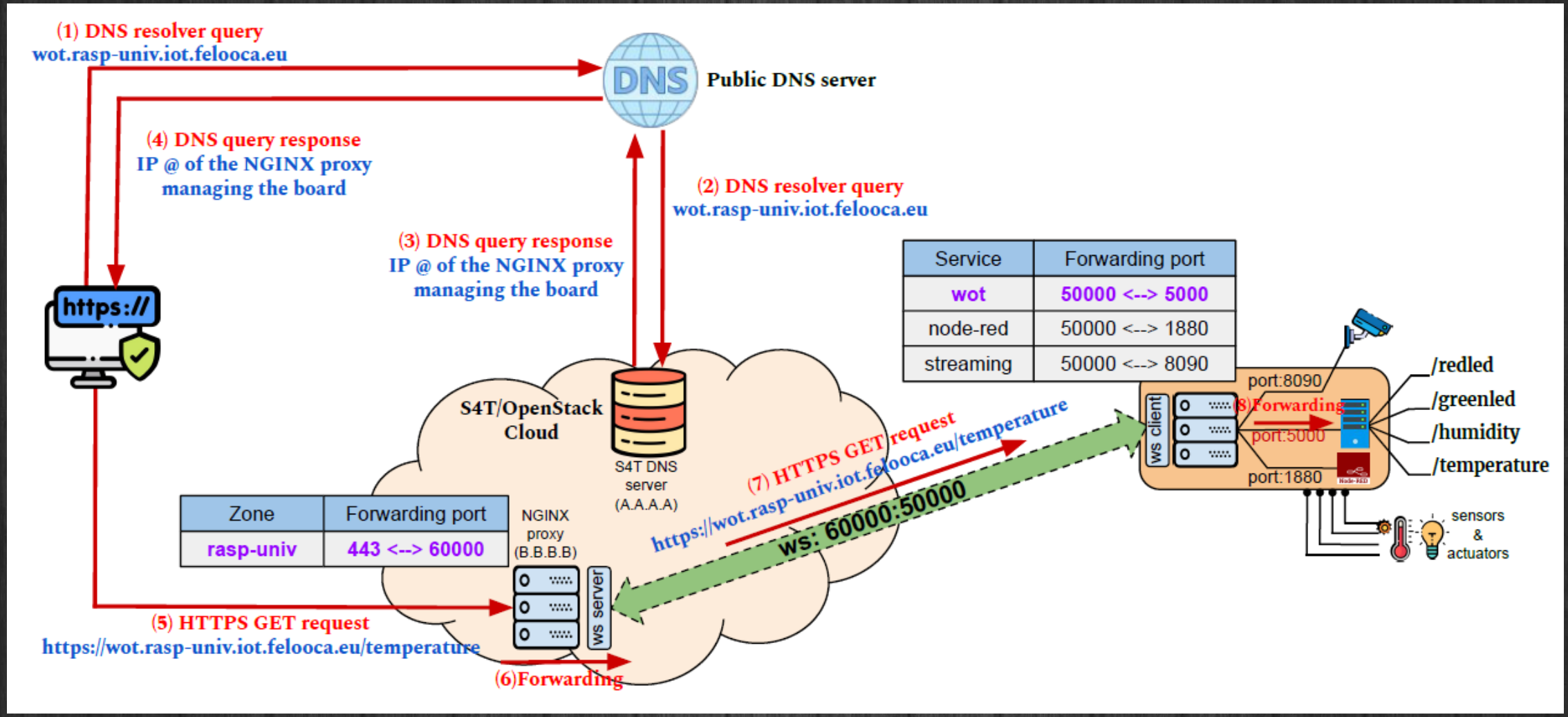


- The S4T device-side agent Lightning-Rod (LR) manages the configuration of the devices.
- Manage/associate unique URLs with the services as sub-domains of a public one.
- The NGINX reverse proxy forwards the received requests to the service involved based on the URLs indicated.
- HTTPS is used to enhance the security of the approach.
- Let's Encrypt CA and Certbot are used to manage X.509 certificates issuance.

For a short demo:

https://wot.rasp-univ.iot.felooca.eu/

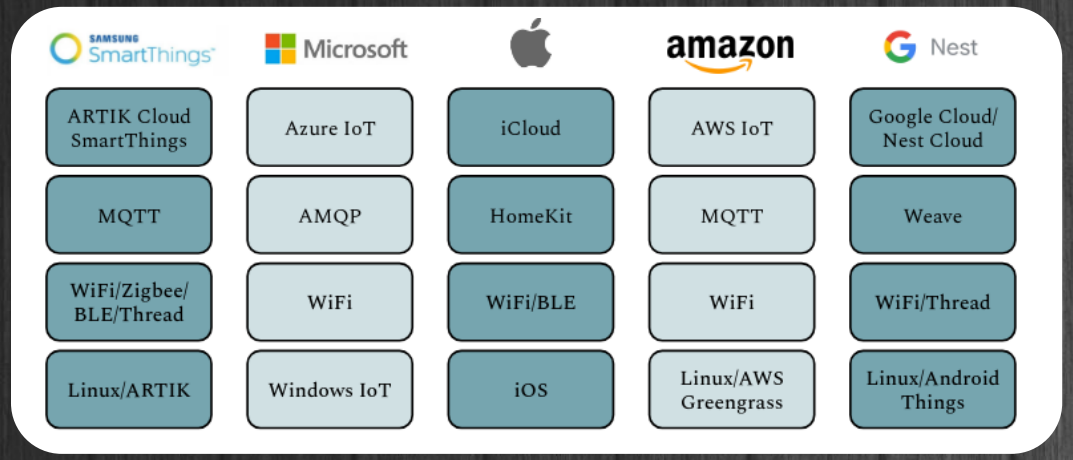
Stack4Things WEB OF THINGS



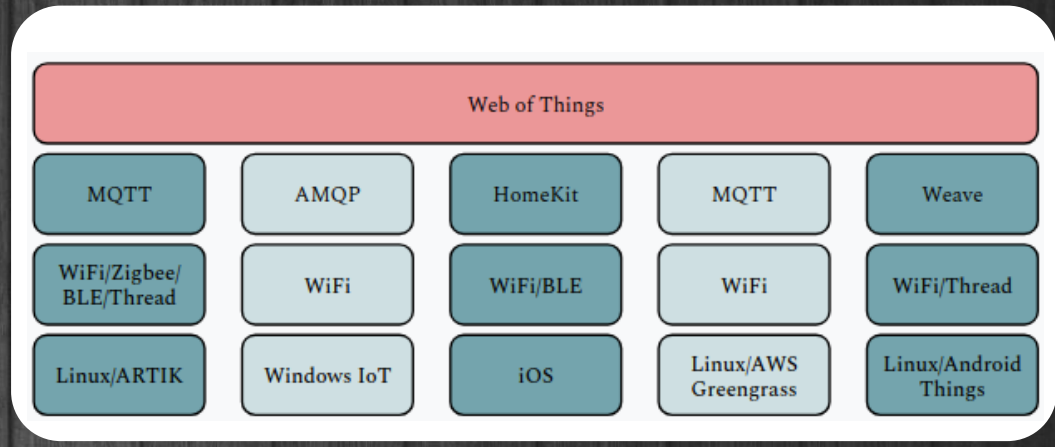
For a short demo:

https://wot.rasp-univ.iot.felooca.eu/

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.felooca.eu/

All interactions here are HTTPS based.

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[4] **D.Bruneo et al.** I/Ocloud: Adding an IoT Dimension to Cloud Infrastructures.

[5] **Z.Benomar et al.** Extending Openstack for Cloud-Based Networking at the Edge.

[6] **F.Longo et al.** Stack4Things: a sensing-and-actuation-as-a-service framework for IoT and cloud integration.

[7] **D.Bruneo et al.** Head in a Cloud: An approach for Arduino YUN virtualization.

[8] **Z.Benomar et al.** A Stack4Things-based Web of Things Architecture

[9] **S.Distefno et al.** Device-Centric Sensing: An Alternative to Data-Centric Approaches.

[10] **N.Tapas et al.** Blockchain-Based IoT-Cloud Authorization and Delegation.

THANK YOU
FOR
YOUR ATTENTION

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Projects links:

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