



UNIVERSITÀ
DEGLI STUDI
FIRENZE

DINFO
DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

DISIT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB

www.disit.org

Course: Security and Privacy

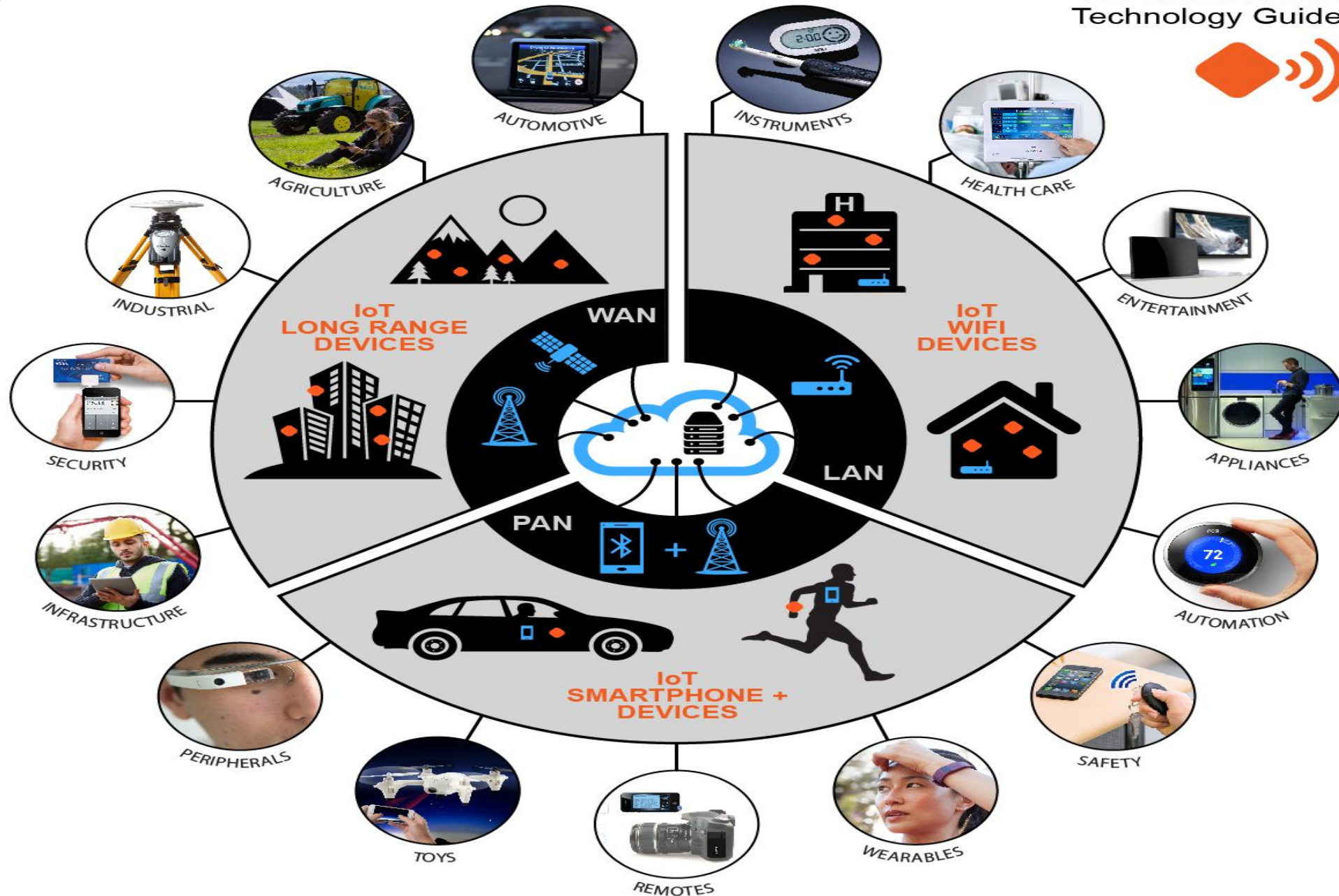
Part on Privacy by Paolo Nesi
Topic: IoT Networks Security

University of Florence, DISIT lab, <https://www.disit.org>

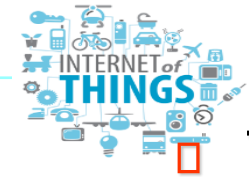
<https://www.snap4city.org>

Paolo.nesi@unifi.it



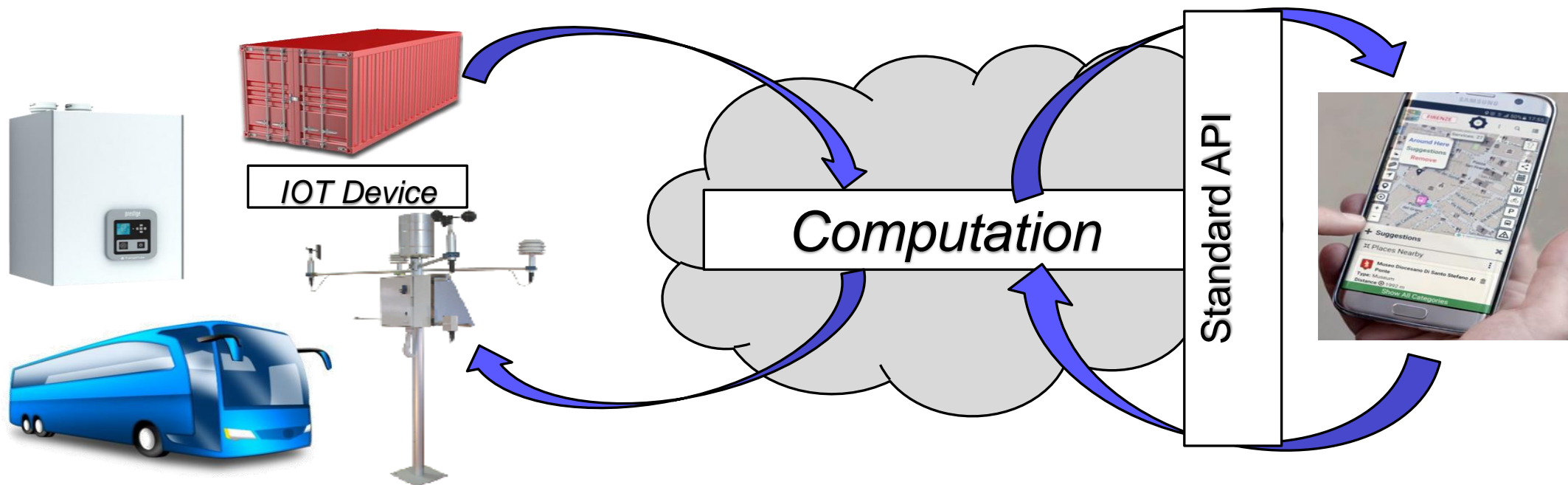


IOT Main Concept

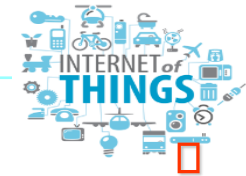


The implementation of smart services may implies the:

- ♣ acquisition of data from the field
- ♣ computation and imposition of actions/values
- ♣ Save of historical values, computer data analytics, etc.

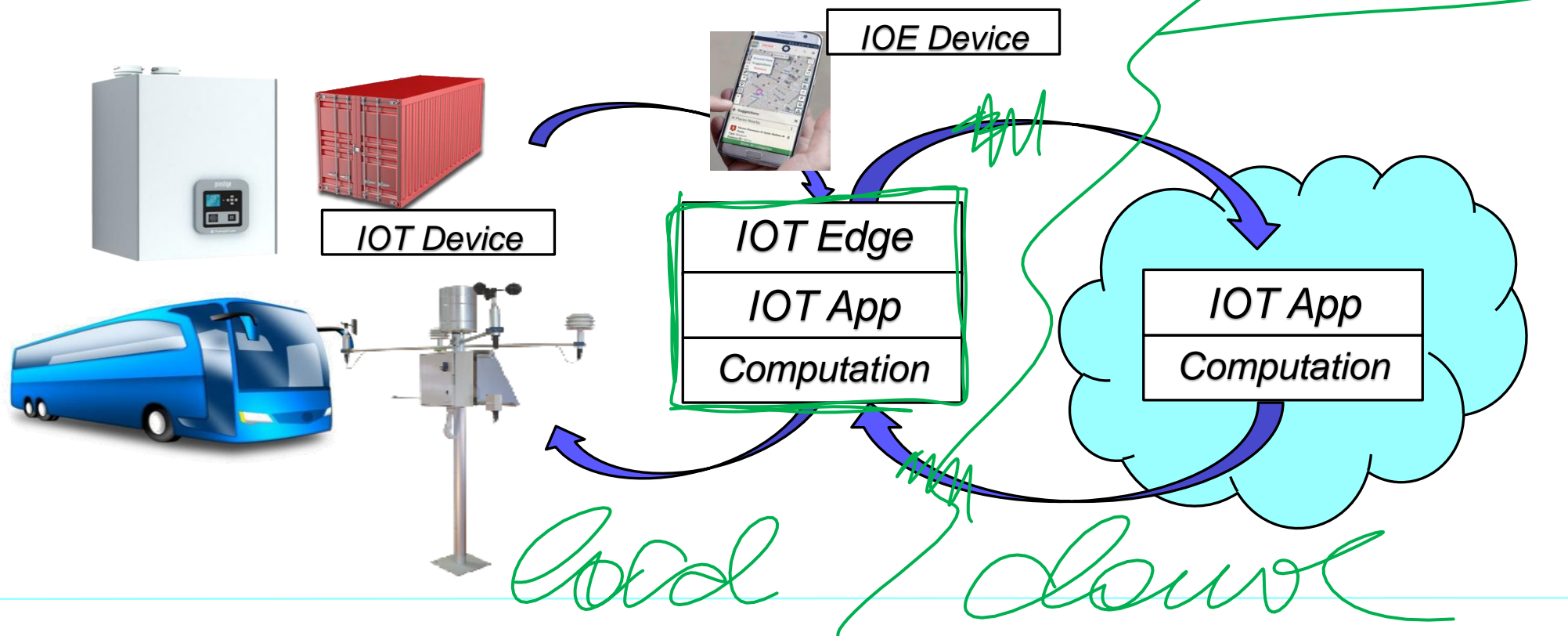


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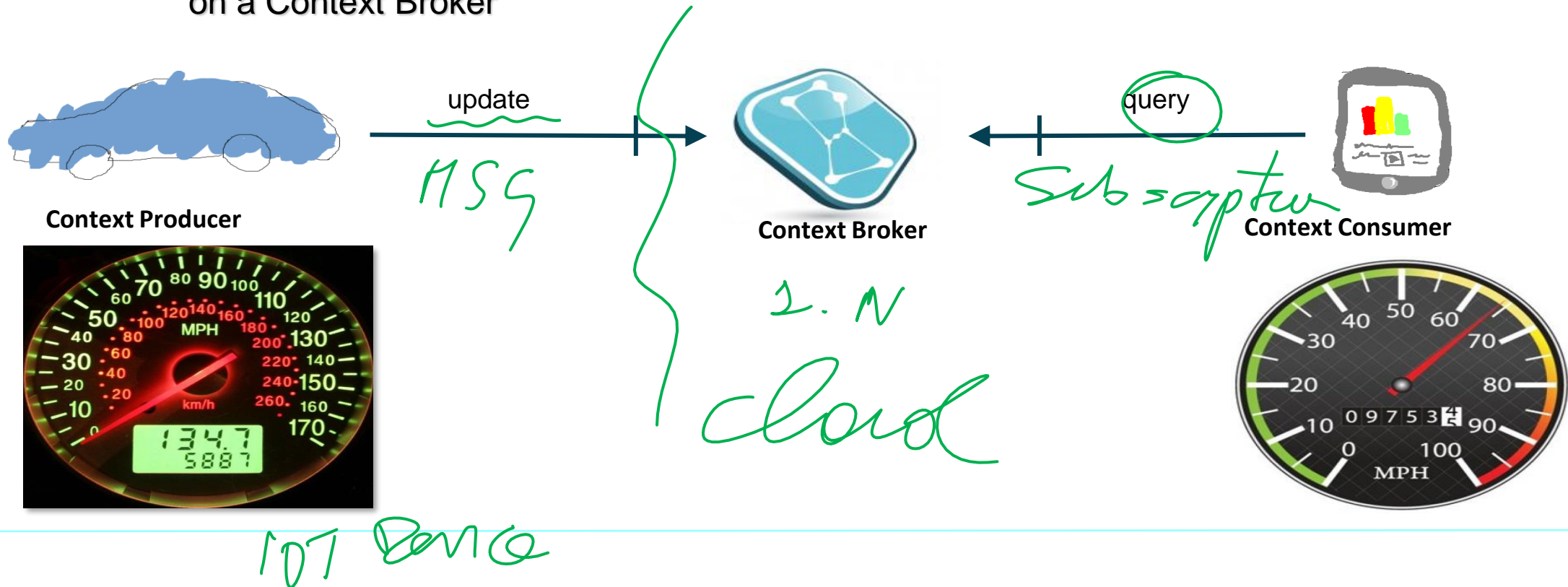


IOT Context Broker

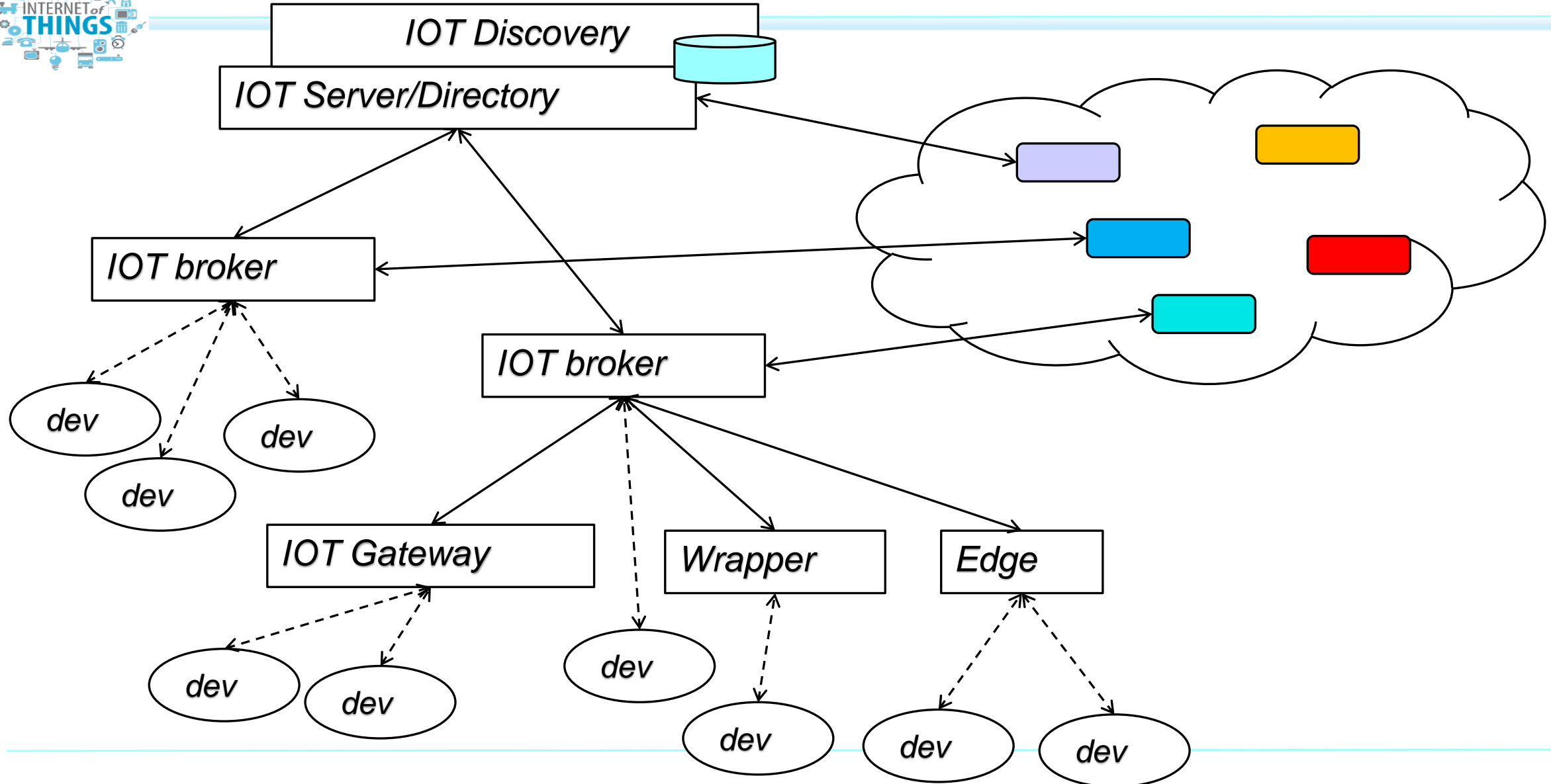


Context Broker operations: **create** & **pull** data

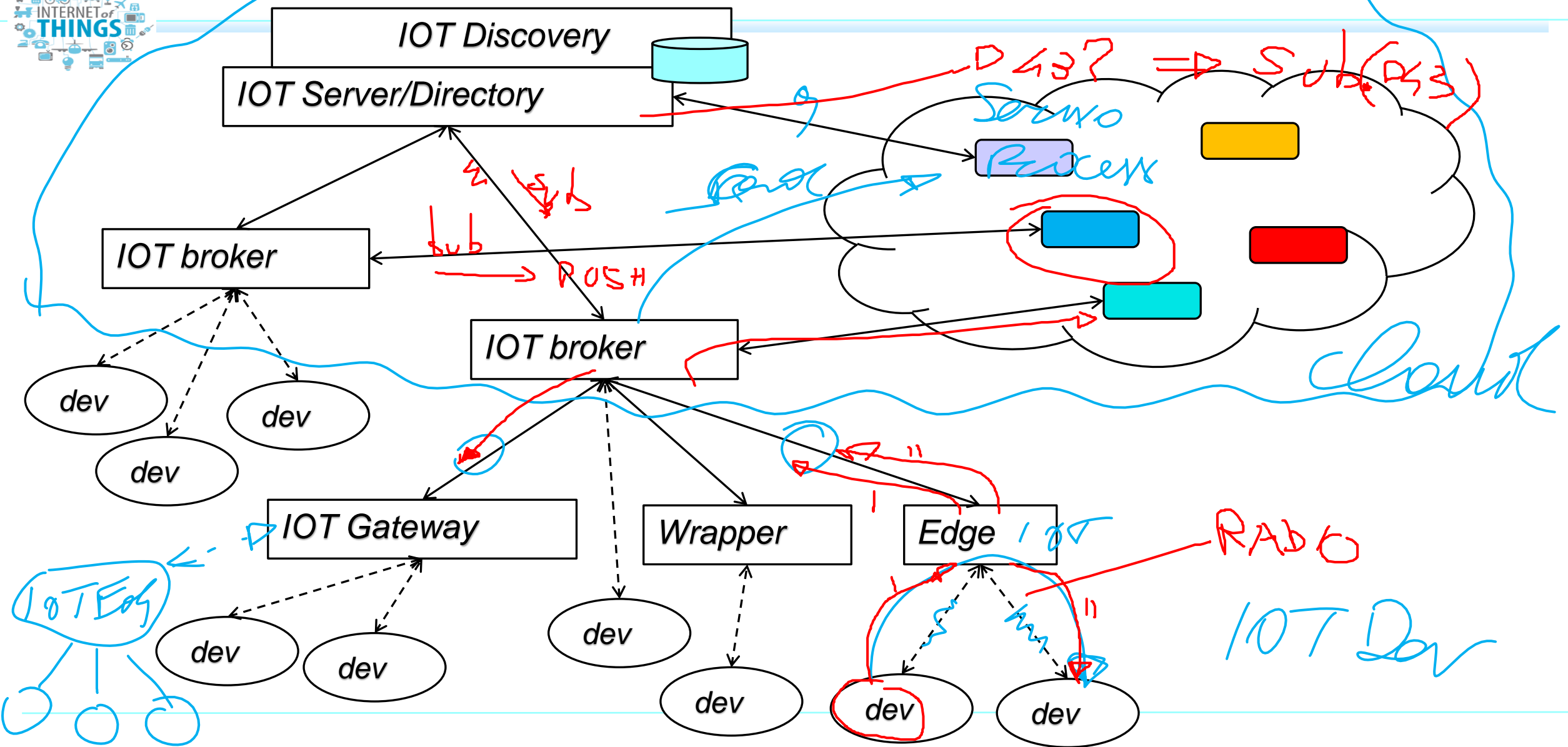
- Context Producers publish data/context elements by invoking the **update** operations on a Context Broker.
- Context Consumers can retrieve data/context elements by invoking the **query** operations on a Context Broker

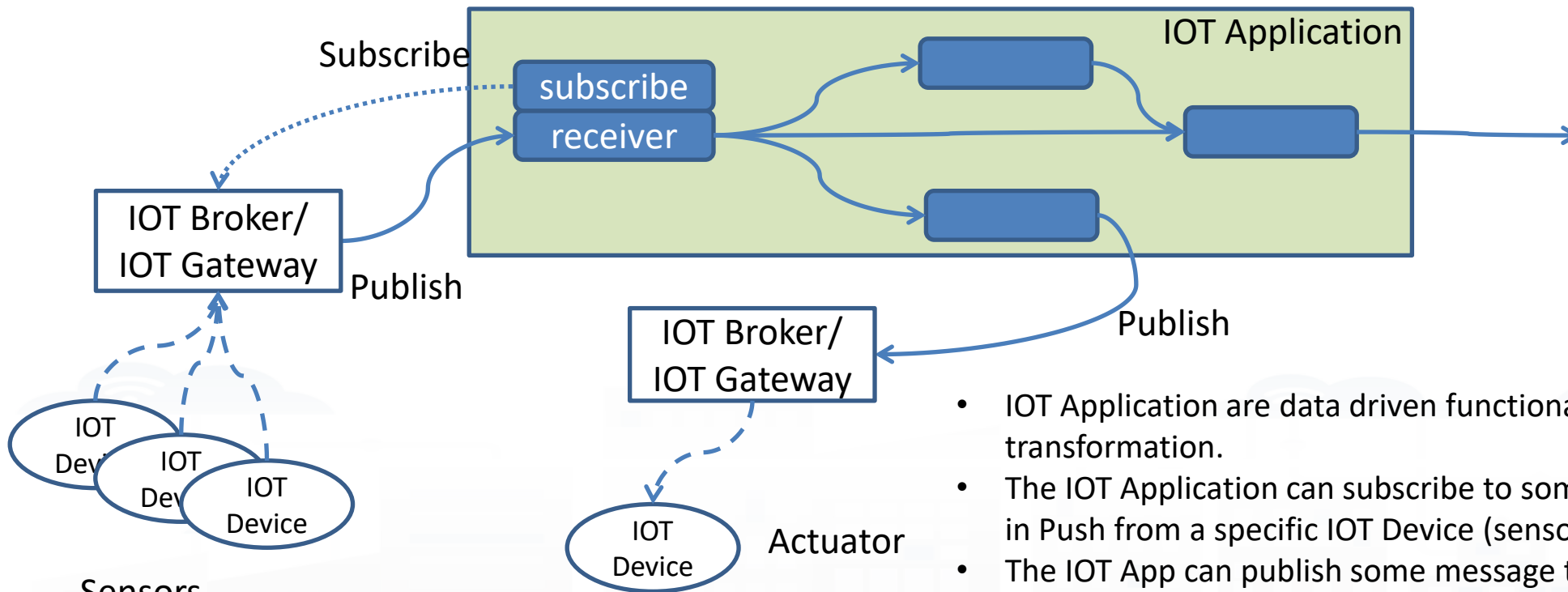


architettura



architettura IOT

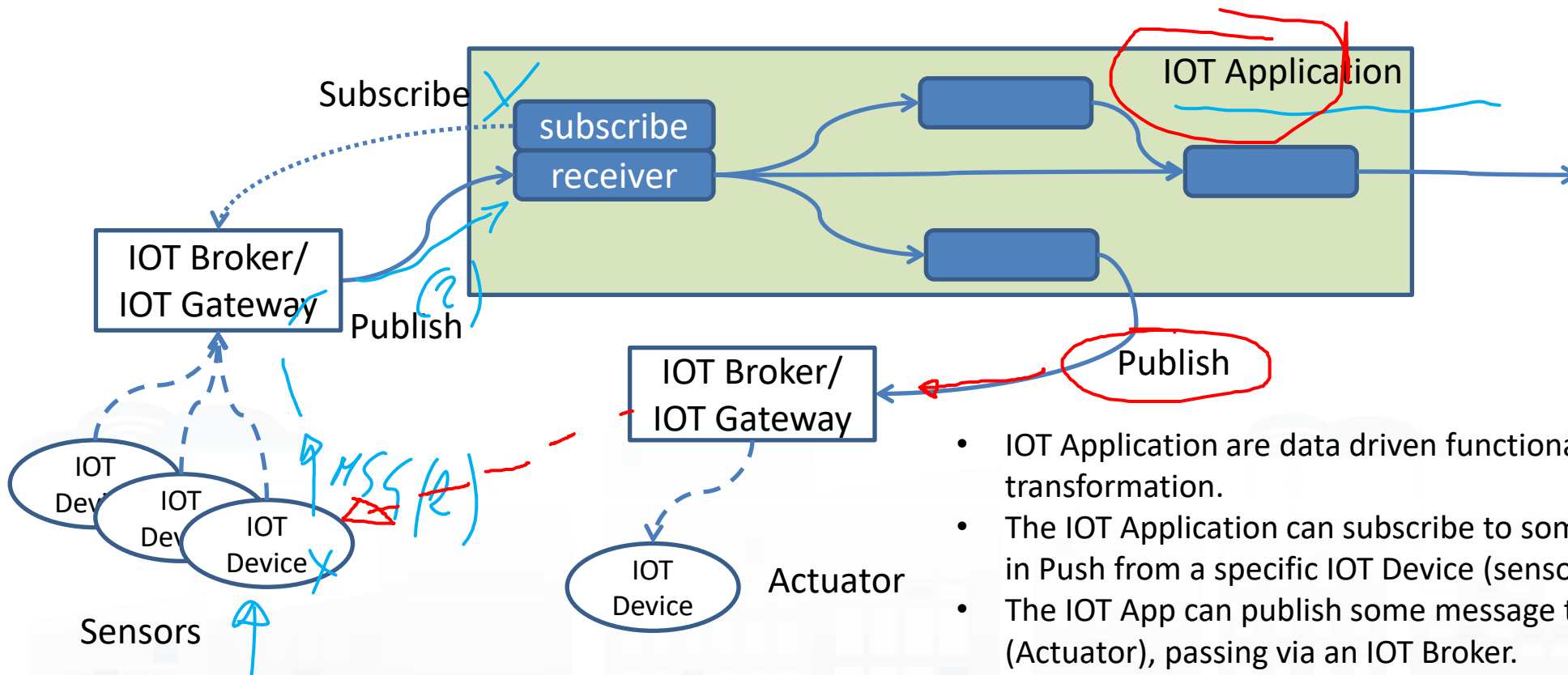




Sensors

- Sensors are programmed to send data (i) periodically, or (ii) when a relevant change occurs in the sensor value, or (iii) when events occur (for example a change of status of something), etc.
- Actuator perform some action on the field: change of status, reset, turn on something, change setting value, etc.

- IOT Application are data driven functional programs for data transformation.
- The IOT Application can subscribe to some IOT Brokers to receive data in Push from a specific IOT Device (sensor)
- The IOT App can publish some message toward some IOT Device (Actuator), passing via an IOT Broker.
- Continuous lines are messages via TCP/IP
- Dashed lines are message via some radio channel (Lora, BT, Wi-Fi, ...)
- IOT Brokers and IOT Gateway can be distinct servers
- IOT Brokers can be on cloud
- IOT Gateway performs the SW update, the business management, access in Push and Pull

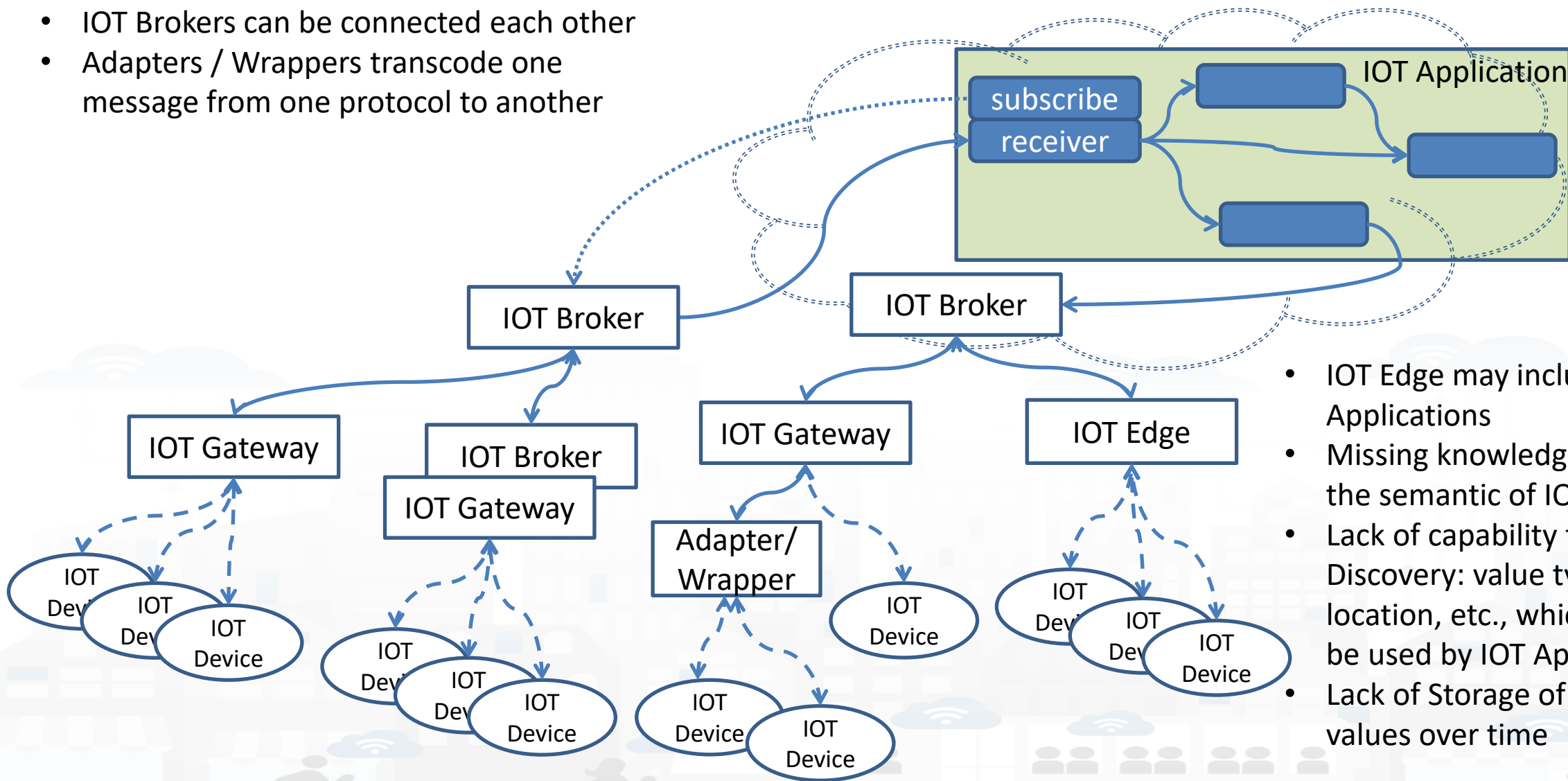


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Definitions

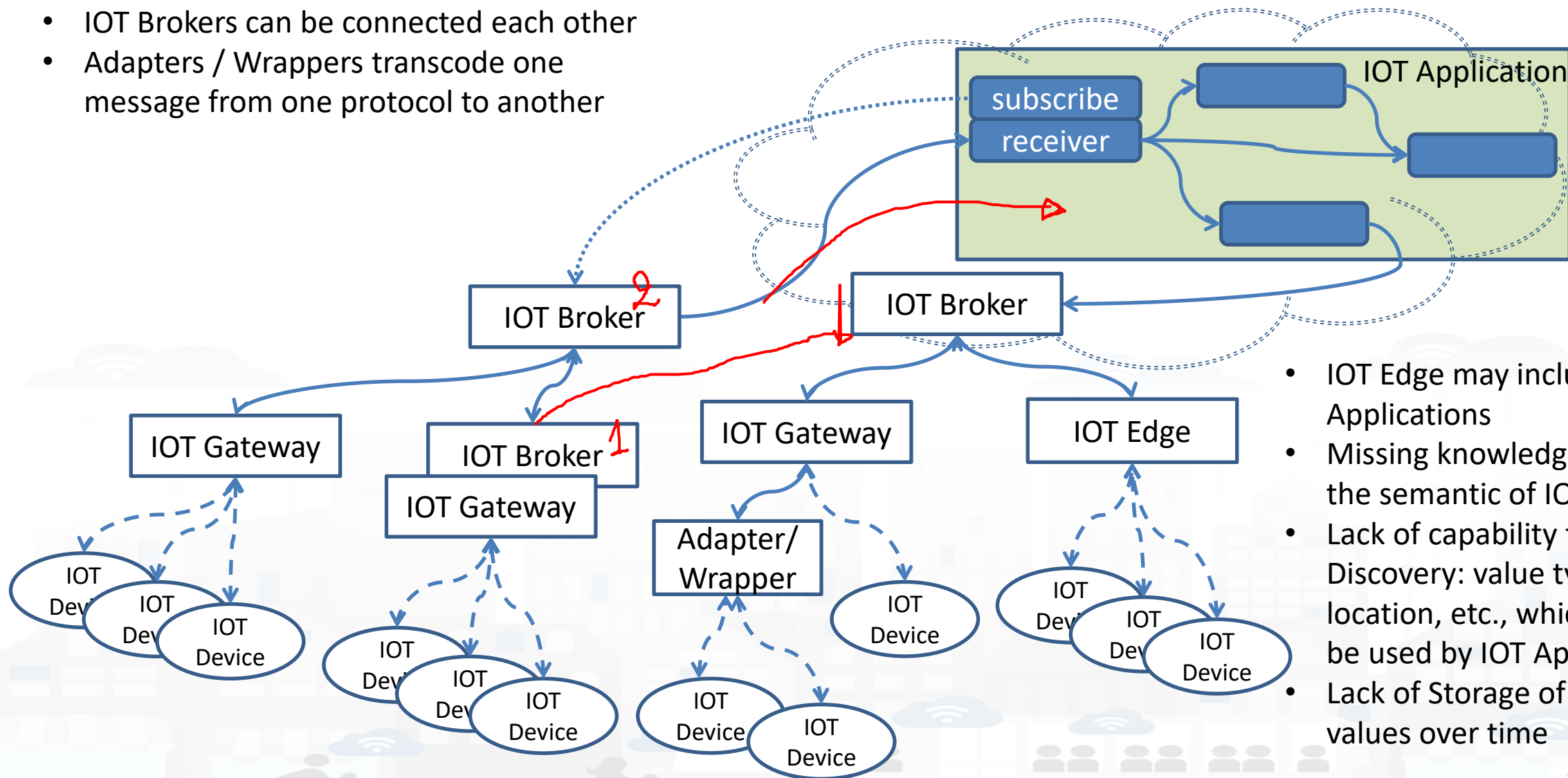
- IOT Brokers can be connected each other
- Adapters / Wrappers transcode one message from one protocol to another



- IOT Edge may include IOT Applications
- Missing knowledge about the semantic of IOT devices
- Lack of capability for IOT Discovery: value type, location, etc., which could be used by IOT App
- Lack of Storage of data values over time

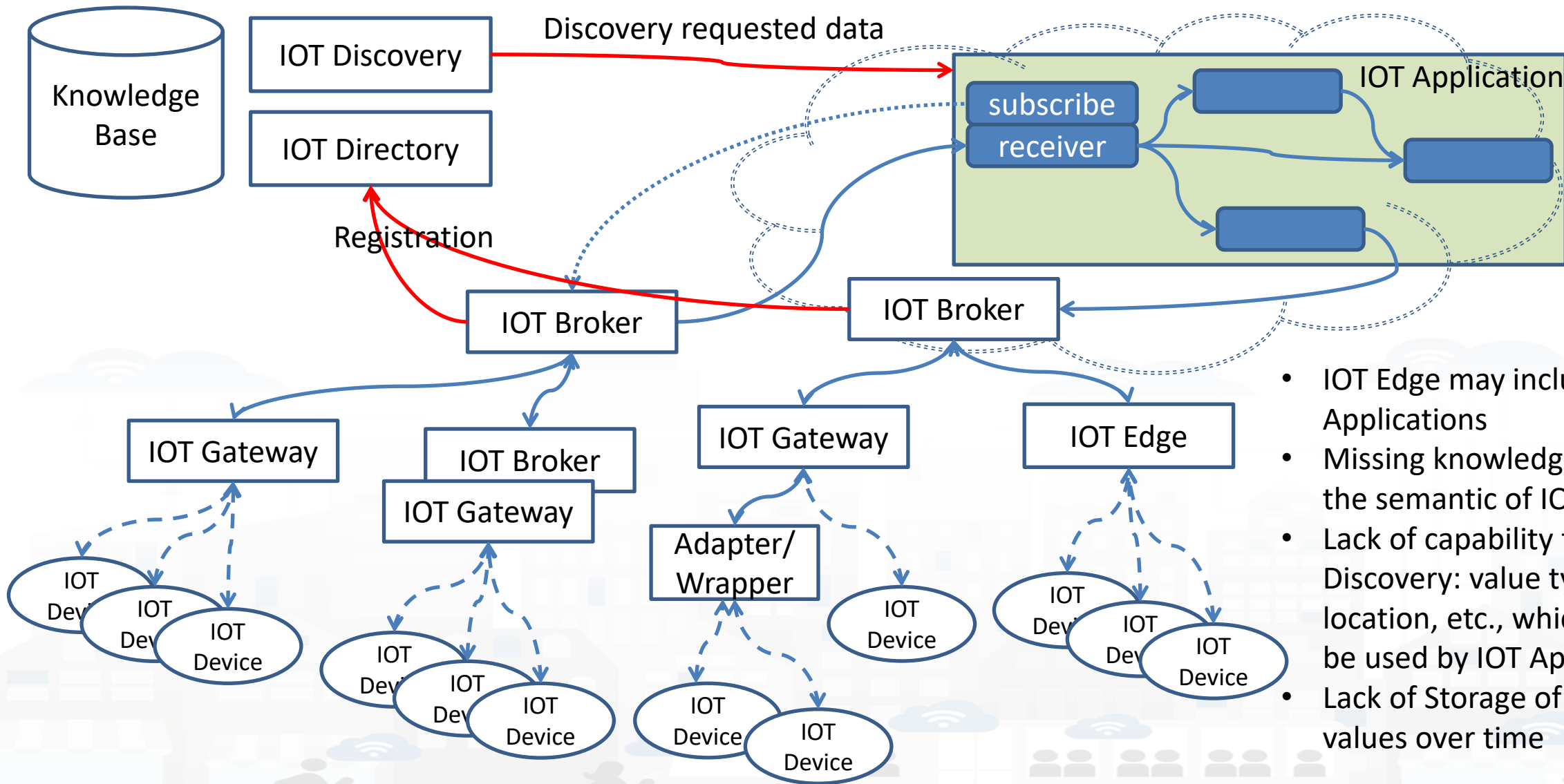
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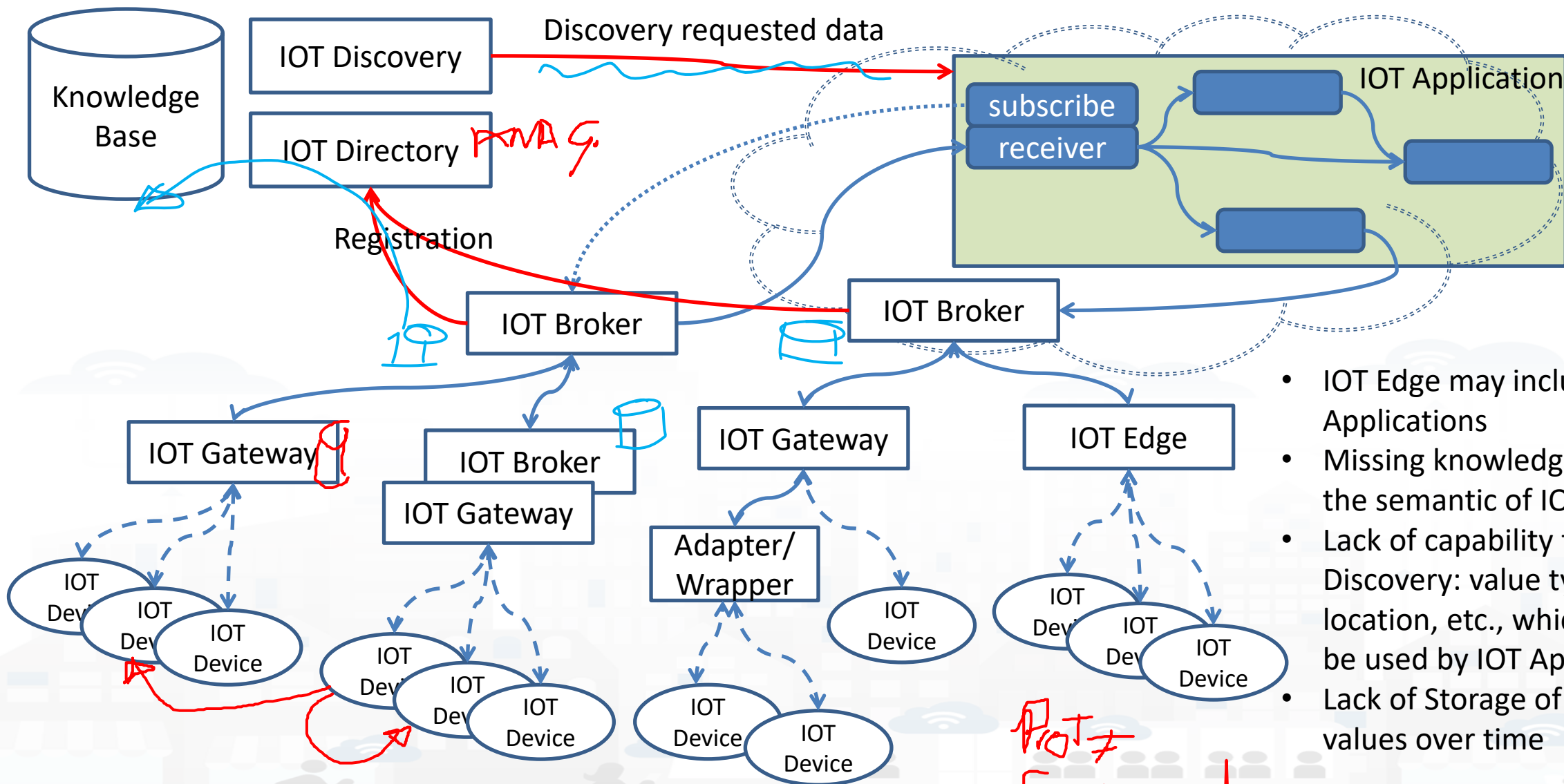
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*IoT ≠
Form ≠ JSON, XML*

Communication Patterns



Broker
Gateway

Discovery

Discover, register and "thrust" new devices on the network

Registration



Broker
Gateway

Telemetry

Information Flows From device to another system for conveying status changes in the device

Push



Brokers
Gateways

Inquiries

Requests from devices looking to gather required information or asking to initiate activities



Broker
Gateway

Commands

Commands from other systems to a device or a group of devices to perform specific activities

Bulk action



Broker
Gateway

Notifications

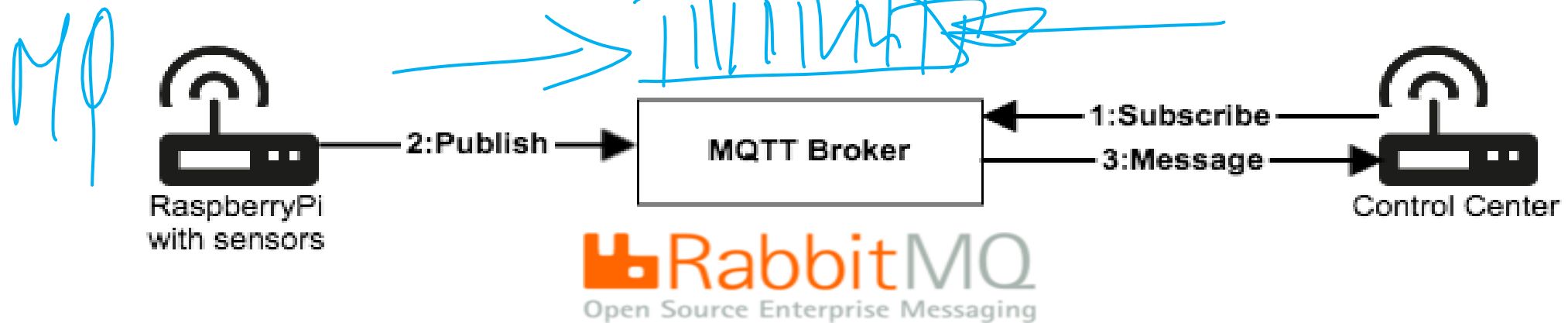
Information flows from other systems to a device or a group for conveying status changes in the world

- MQTT
- HTTP(s)
- AMQP
- COAP
- NGSI
- OneM2M
- WebSockets
-
- Etc.

IOT Brokers



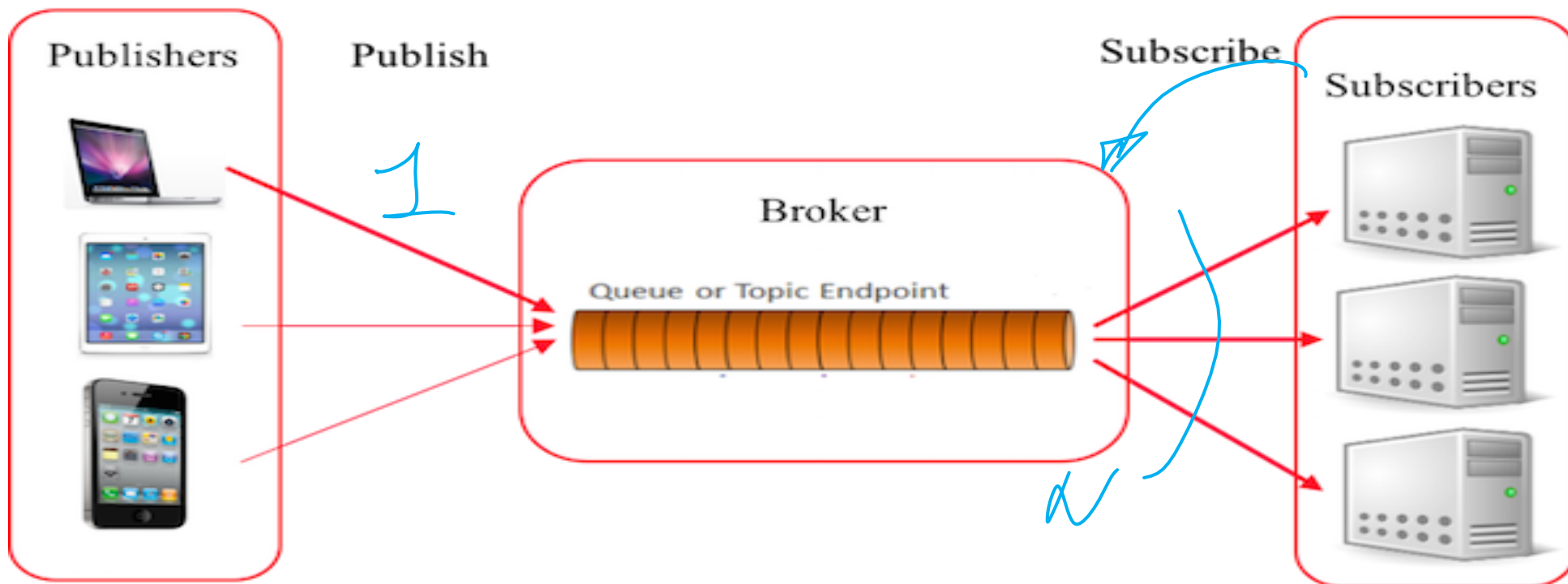
	AMQP	STOMP	JMS	COAP	NGSI	MQTT OASIS
RabbitMQ	X	X	X	X		X
Mosquitto						X
ActiveMQ	X	X	X			X
StormMQ	X					
HIVEMQ			X			X
ORION BROKER				X	X	X



MQTT: Message Queue Telemetry Transport



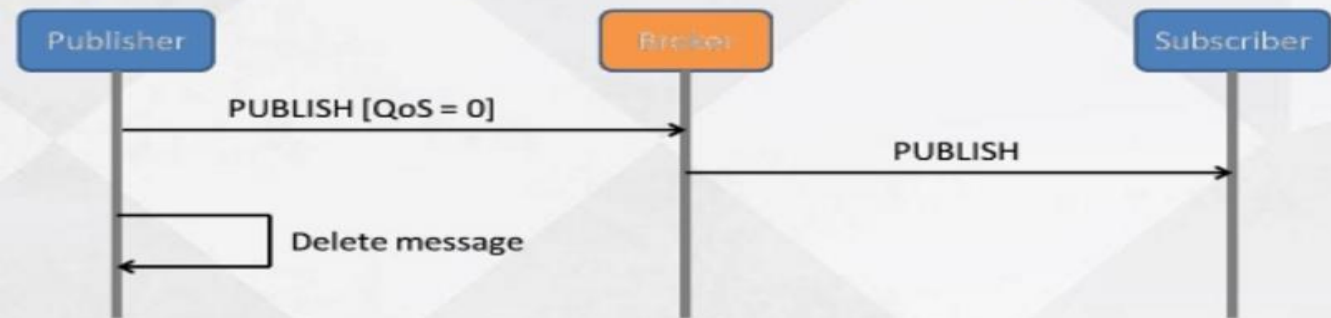
- ❑ security obtained with SSL/TLS since it is over TCP
- ❑ ISO/IEC PRF 20922
- ❑ Over TCP/IP, Async, pub/subscribe,
- ❑ payload agnostic (can be encrypted)



MQTT QoS



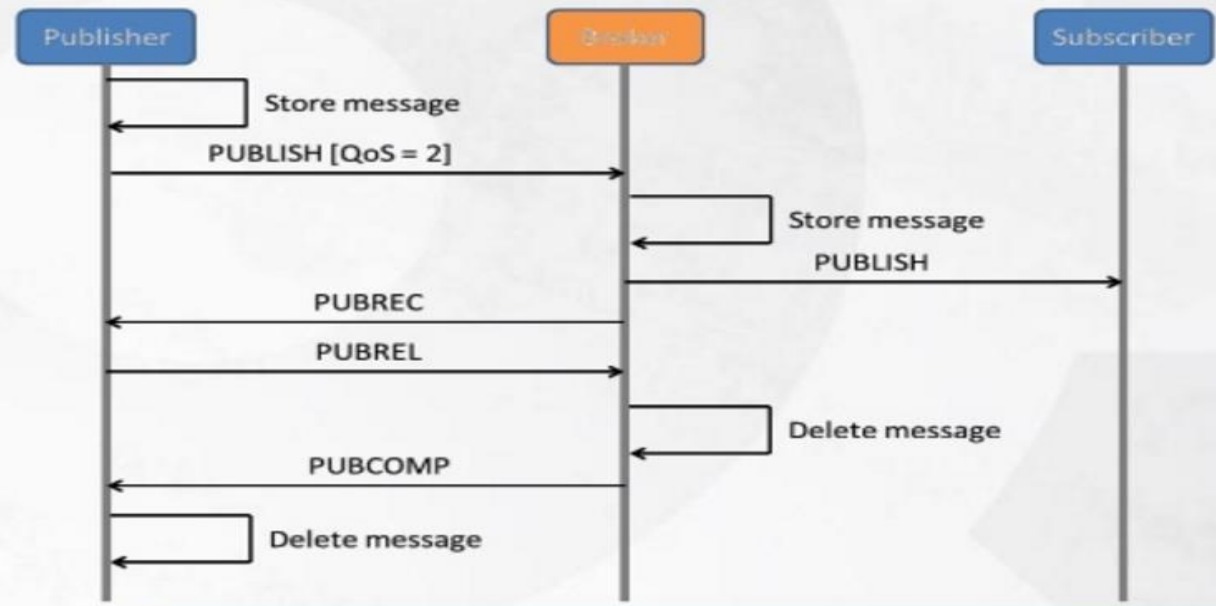
QoS 0 : At most once (fire and forget)



QoS 1 : At least once



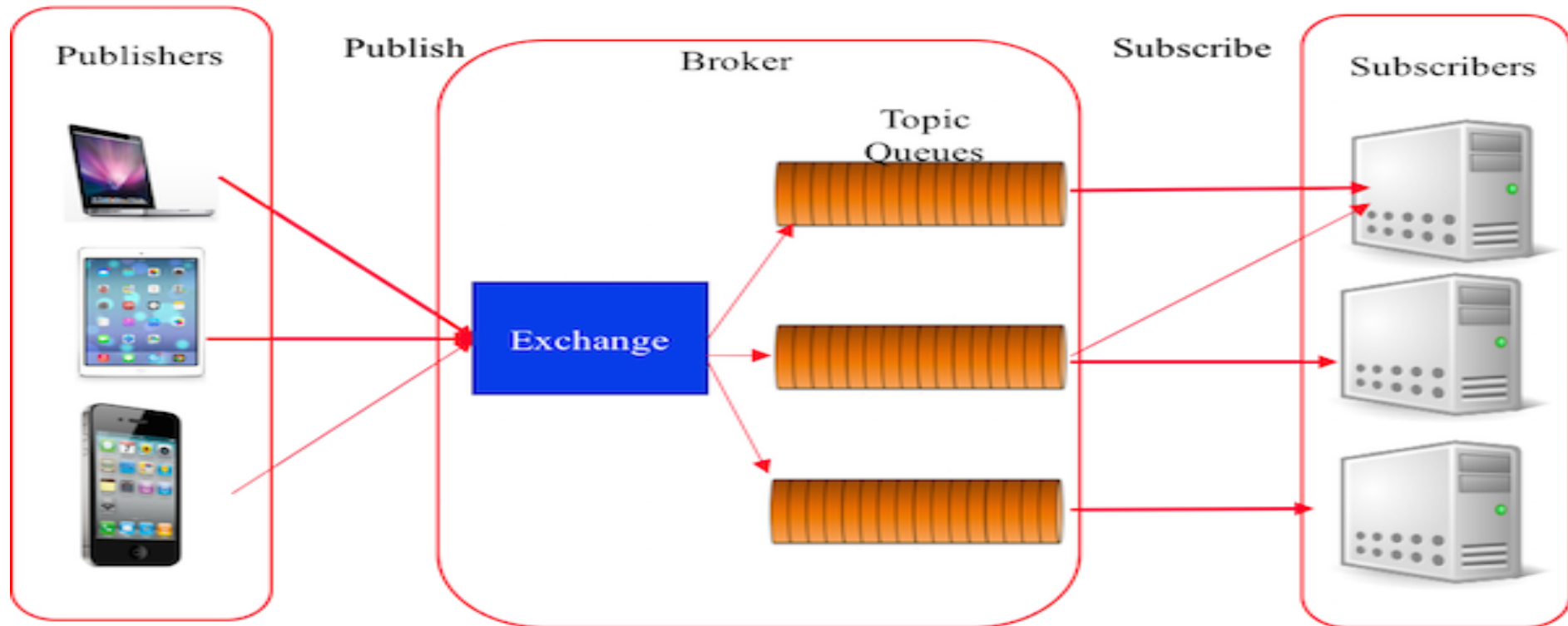
QoS 2 : Exactly once





AMQP Advanced Message Queuing Protocol

- ❑ Over TCP, binary wire protocol
- ❑ Exchange decoupling





- “a **dynamic global network infrastructure** with self-configuring capabilities based on standard and interoperable communication protocols where **physical and virtual ‘Things’** have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network” Institute of Network Cultures
- “a global infrastructure for the information society enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technology” ITU-T (2012) Next Generation Networks

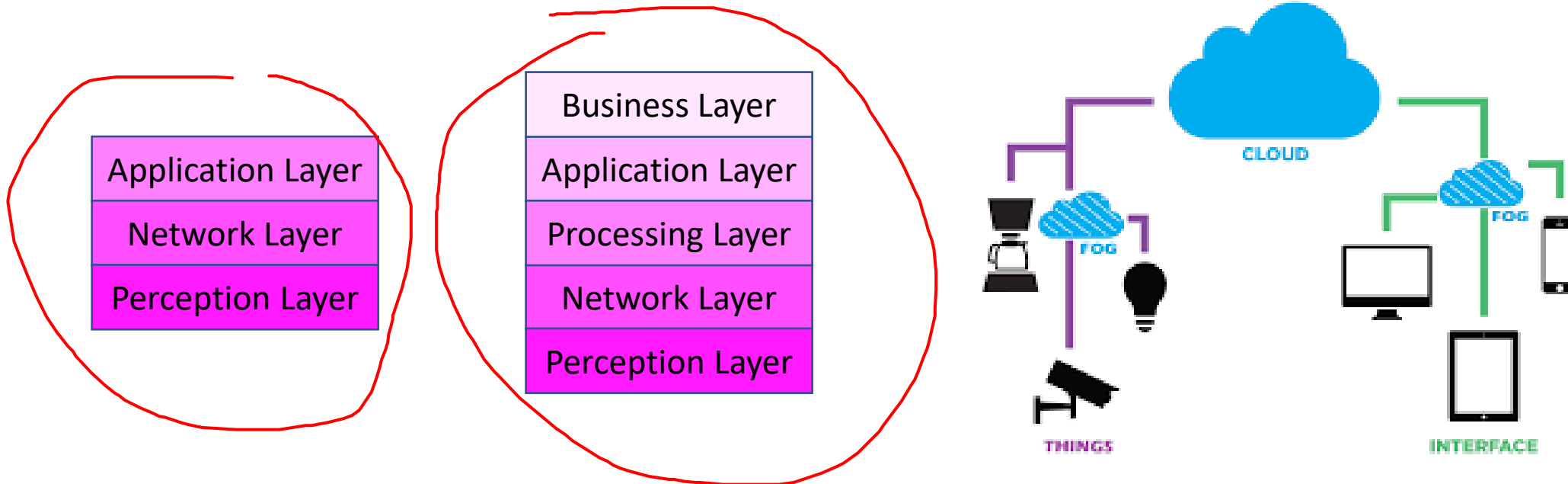


- Independent **IoT ecosystems** that can be
 - physical
 - virtual
 - hybrid mix of the two
- consist of a list of **active** physical devices, sensors, actuators, services, communication protocols and layers, final users, developers and interface layers

IoT architecture

- Several functional blocks are defined in an IoT system, even if a **common conceptualization is not found**, but several different approaches are usual considered: 3-layer, 5-layer, cloud and fog systems, social IoT paradigms.

S — BL — UI



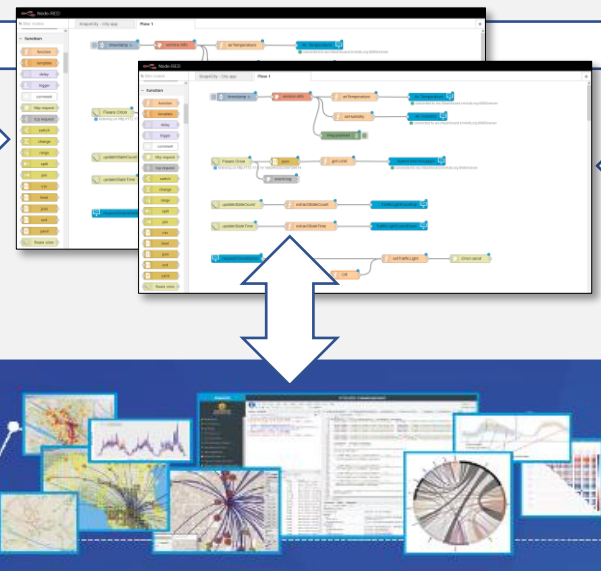
IoT Sentient solutions

IoT and City data World



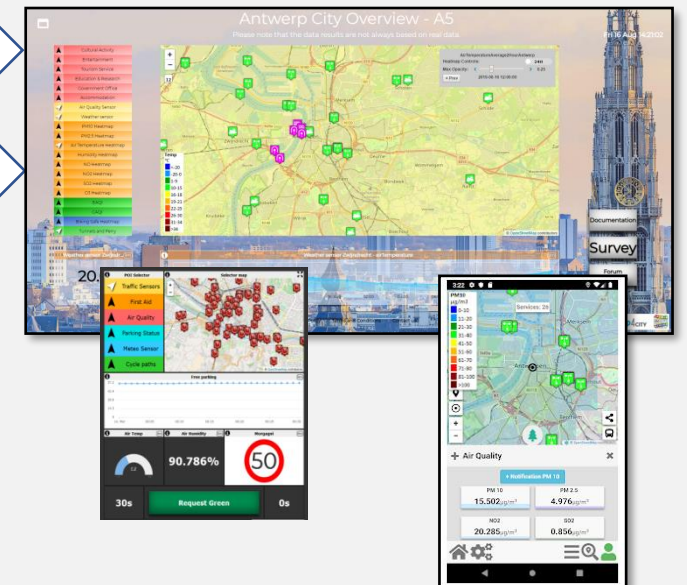
My IoT Devices

IoT Applications



Big Data Analytics, Artificial Intelligence

Dashboards and Apps



Azure IoT

AWS

Google IoT

Data di rilascio (Out of beta)

Febbraio 2016

Dicembre 2015

Febbraio 2018

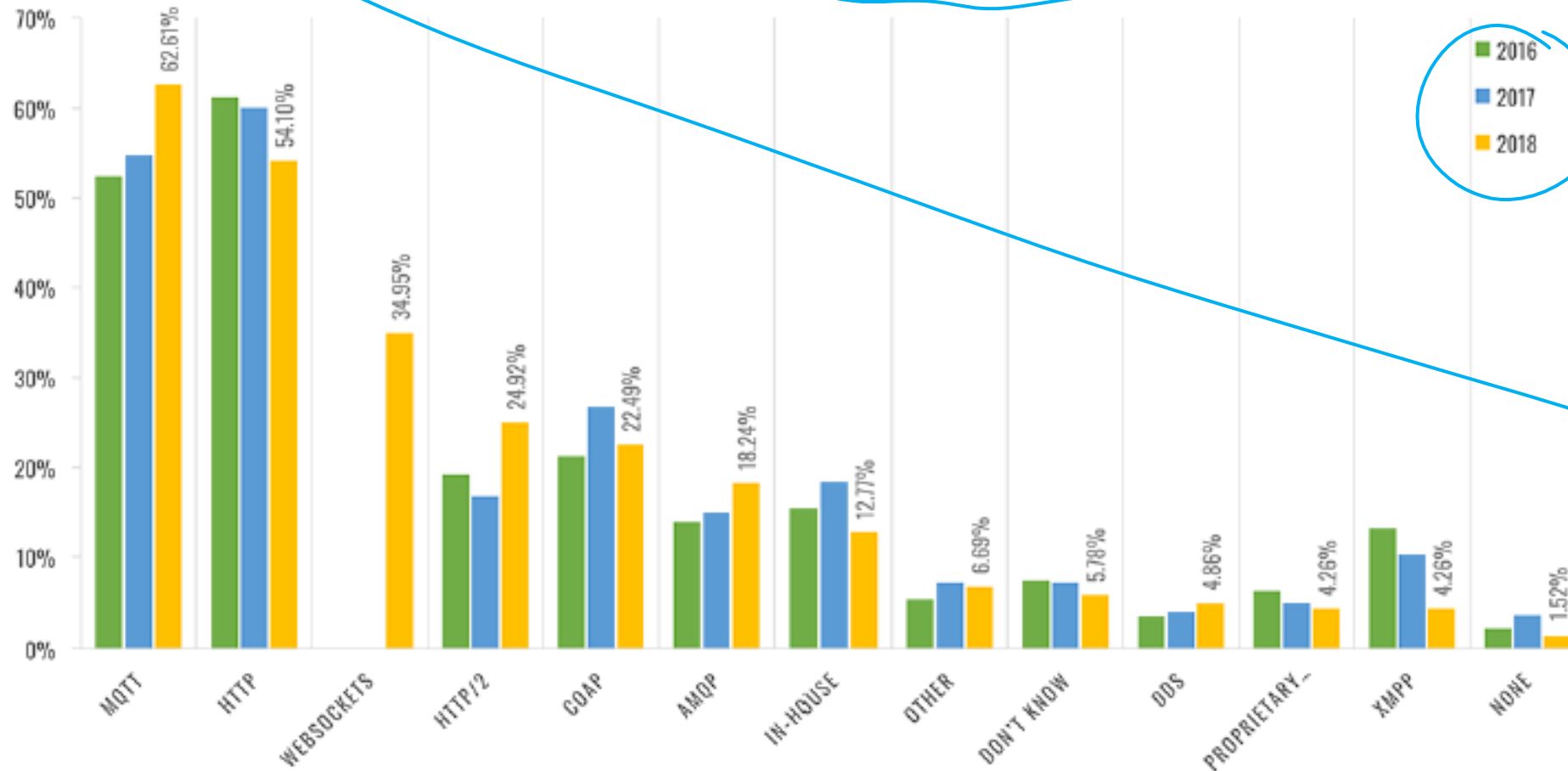
Quota di mercato

31.21%

51.82%

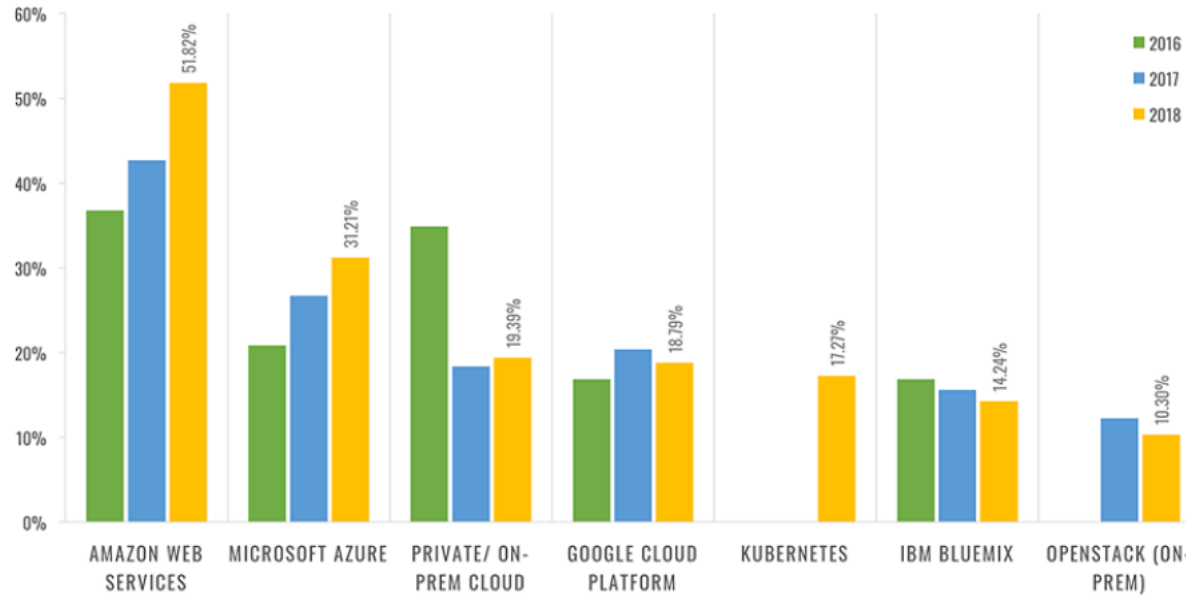
18.79%

2019

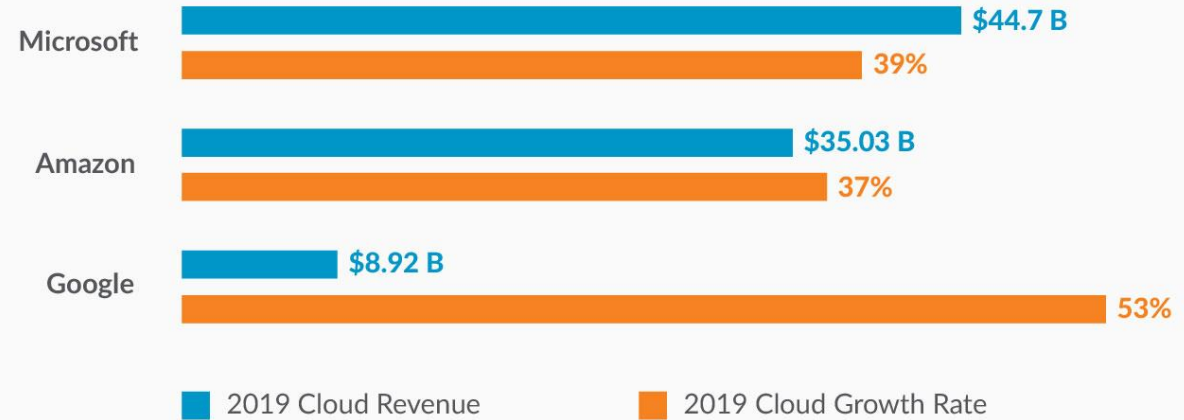




State-of-the-art IoT architecture



Cloud Wars: AWS vs Azure vs GCP



Small-medium businesses.
Partners with Cisco
to reach enterprises



Enterprises



Any, but with a hands-off
approach due to its
enormous size

	Azure IoT	AWS	Google IoT
Data di Rilascio (Out of Beta)	Febbraio 2016	Dicembre 2015	Febbraio 2018
Documentazione	Ottima	Molto Buona	Sufficiente
Certificazione	Ottenibile inviando l'applicazione sviluppata	Ottenibile sostenendo esami relativi a specifici ambiti	Ottenibile sostenendo esami relativi a specifici ambiti
Tipologia Certificazione	Non definita	Per specializzazione (Big Data, Security ecc) oppure per ruolo (Architect, Developer ecc)	Cloud Architect, Data Engineer, Suite Administrator
Vantaggi	Logo, crediti, sottoscrizioni, consulenze, accesso alla community ed eventi	Accesso alla community, logo, merchandise, accesso ad eventi	Non previsti

	Azure IoT	AWS	Google IoT
Architettura	Hub che comunica con tutti gli altri servizi.	I dati vengono raccolti dal Rules Engine e dal Device Shadows. A partire da questi si attivano i vari servizi.	Core che comunica con Funzioni, Pub/Sub e Dataflow. Questo si interfaccia agli altri servizi
API	REST	REST	REST
Protocolli	MQTT, AMQP, MQTT on WebSocket, AMQP on WebSocket, HTTPS, (1)	MQTT, MQTT on WebSocket, HTTPS	MQTT, HTTP
Sicurezza	TLS	TLS (mutual)	TLS
Autenticazione	SAS Token, IAM, x.509	x.509, IAM, Amazon Cognito, Federated, (2)	JSON Token, IAM, x.509
SDK	.NET, Java, Node.js, C, Python, (3)	C, Javascript, Java, Python, IOS, Android, Arduino Yun	Go, Java, .NET, Javascript, IOS, Android, PHP, Ruby, Python
Starter Kit	Intel, Raspberry Pi, Freescale, Texas Instruments, Seeed, resin.io, MinnowBoard, BeagleBoard	Broadcome, Marvell, Renesas, Texas Instruments, Intel, Microchip, Seeed, Mediatek, Qualcomm, BeagleBoard	Microchip, Adafruit, Marvell, TechNexion, Grove, Realtek, Allwinner, MangOH.

	Azure IoT	AWS	Google IoT
Edge			
Storage	Blob, CosmosDB, SQL		
Big Data		?	?
Data Visualization	Power Bi		
Artificial Intelligence	X	X	X
Intelligence API	Language, Speech, Vision, Knowledge	X	/

	Azure IoT	AWS	Google IoT
Prezzo	Diverse fasce di prezzo in base al numero di messaggi scambiati	Costo unitario per messaggio e per tempo di connessione del dispositivo	Costo basato sul volume di dati scambiati

	Azure IoT	AWS	Google IoT
Sicurezza	TLS	TLS (mutual)	TLS
Autenticazione	SAS Token, IAM, x.509	x.509, IAM, Amazon Cognito, Federated Identities	JSON Token, IAM, x.509

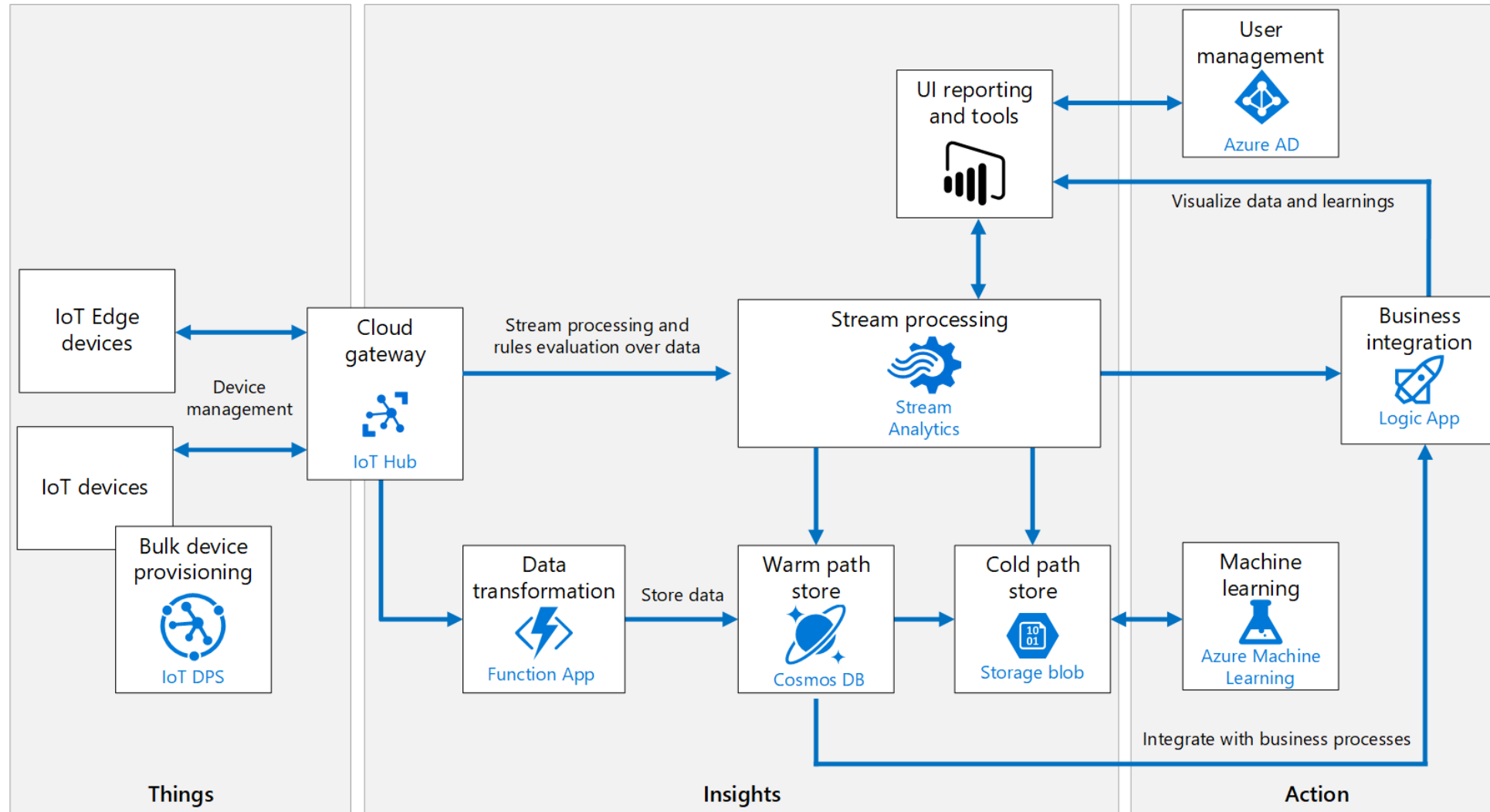
	Azure IoT	AWS	Google IoT
Protocolli	MQTT, AMQP, MQTT on WebSocket, HTTPS, AMQP on WebSocket	MQTT, MQTT on WebSocket, HTTPS	MQTT, HTTP
Communication Patterns	Telemetry, Query, Notification, Command	Telemetry, Query, Notification, Command	Telemetry, Query, Notification, Command

	Azure IoT	AWS	Google IoT
Scalability	Scaling da configurare mediante funzione	Servizio di scaling automatico	Servizio di scaling automatico

	Azure IoT	AWS	Google IoT
Rimborsi	10% di rimborso fino al 99%, al di sotto viene rimborsato il 25%	10% di rimborso fino al 99%, al di sotto viene rimborsato il 30%	10% di rimborso fino al 99%, nella fascia fino al 95% viene restituito il 25% e al di sotto di questa il 50%

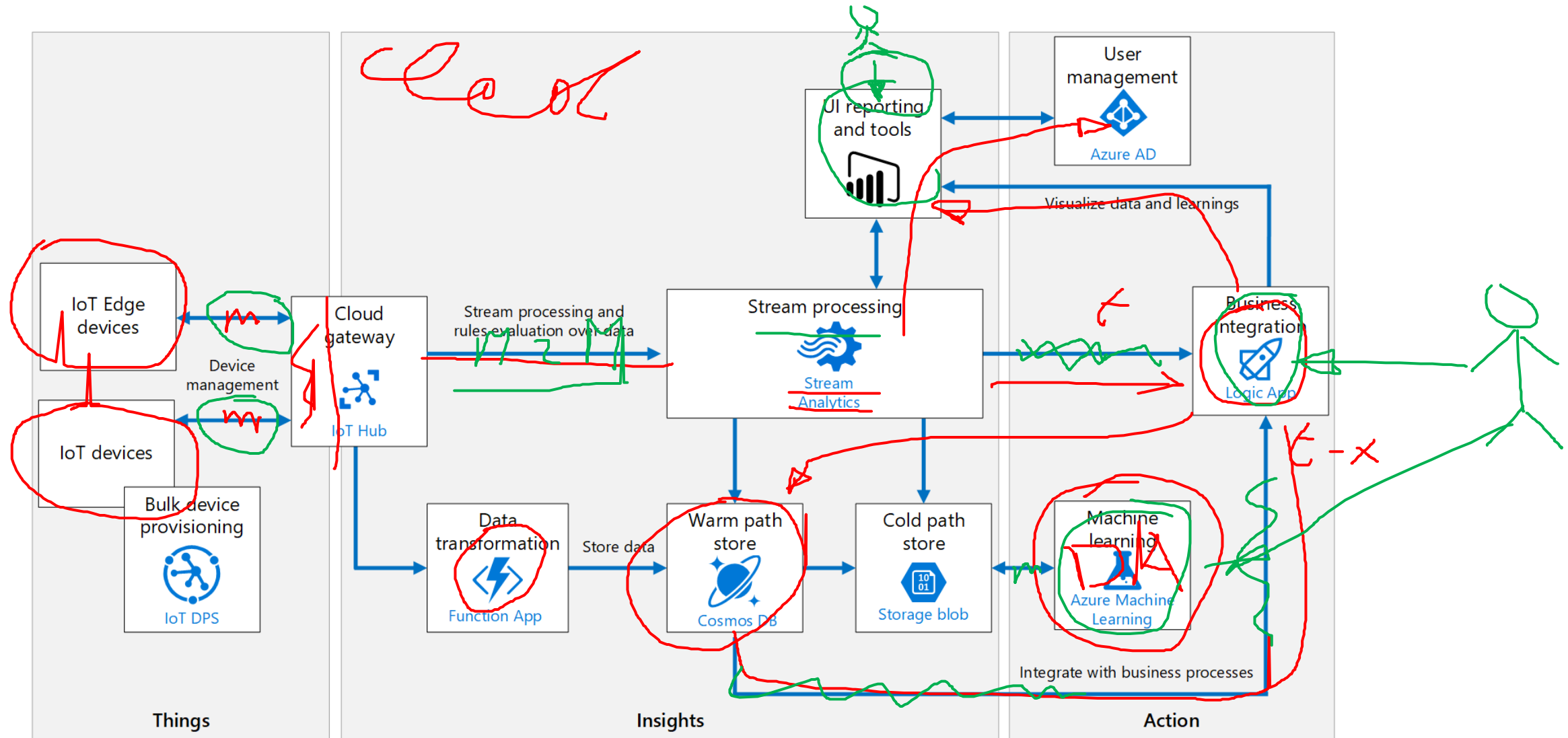


Azure Microsoft IoT (1)





Azure Microsoft IoT (1)





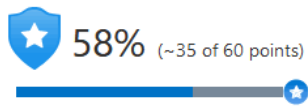
Azure Microsoft IoT (2)

- IoT Hub / Cloud Gateway that communicate with the internal ecosystem
- Supported languages in Azure Functions:
 - C# (Full .NET Framework), Java, Node.js, Python
- communication protocols: MQTT, MQTT over WebSockets, AMQP, AMQP over WebSockets, HTTPS
- Azure Security Center: TLS, SAS Token, IAM, x.509, Role-Based Access Control, Shared Access Signature,

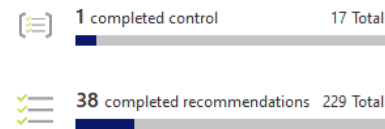


Azure Microsoft IoT (3)

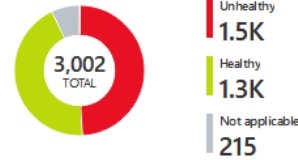
Secure Score



Recommendations status



Resource health

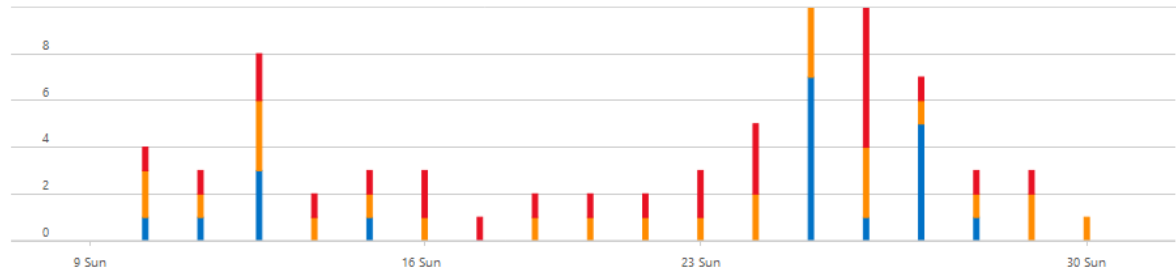


Controls	Potential score increase	Unhealthy resources	Resource Health
> Remediate vulnerabilities	+ 10% (6 points)	171 of 219 resources	
> Enable encryption at rest	+ 5% (3 points)	147 of 231 resources	
> Manage access and permissions	+ 5% (3 points)	20 of 36 resources	
> Remediate security configurations	+ 4% (3 points)	134 of 212 resources	
> Protect applications against DDoS attacks	+ 3% (2 points)	14 of 156 resources	
> Encrypt data in transit	+ 3% (2 points)	135 of 331 resources	
> Apply system updates	+ 3% (2 points)	57 of 212 resources	
> Apply adaptive application control	+ 2% (1 point)	75 of 165 resources	
> Secure management ports	+ 2% (1 point)	14 of 151 resources	
> Apply data classification	+ 2% (1 point)	16 of 53 resources	
> Restrict unauthorized network access	+ 1% (1 point)	48 of 241 resources	
> Enable endpoint protection	+ 1% (1 point)	75 of 192 resources	
> Enable auditing and logging	+ 1% (1 point)	134 of 180 resources	
> Implement security best practices	+ 0% (0 points)	168 of 797 resources	
> Enable advanced threat protection	+ 0% (0 points)	8 of 11 resources	
> Custom recommendations	+ 0% (0 points)	1033 of 2183 resources	
> Enable MFA ✔ Completed	+ 0% (0 points)	None	

Security Center | Security alerts

Showing 40 subscriptions

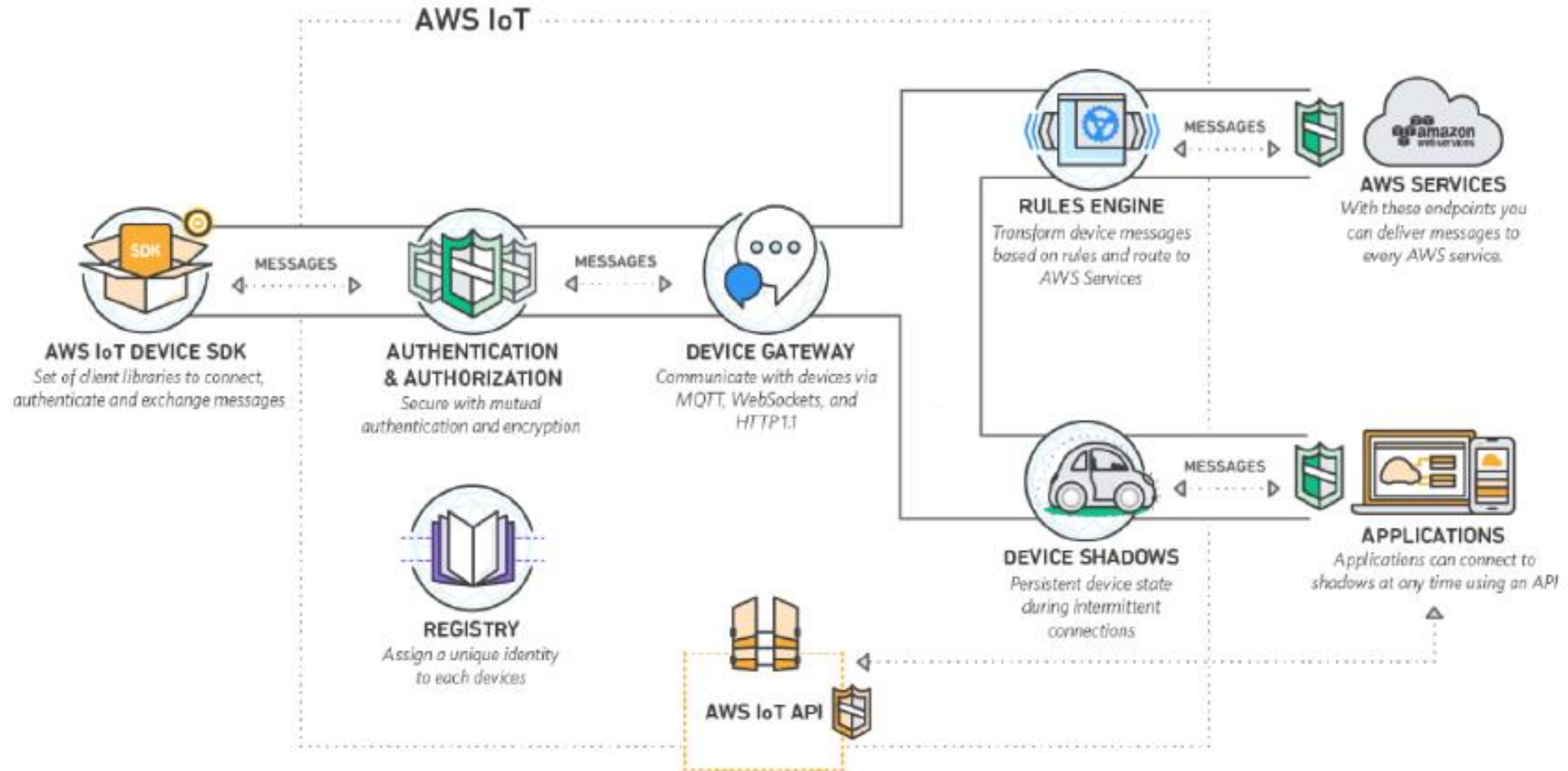
Filter Download CSV report Suppression rules (preview)



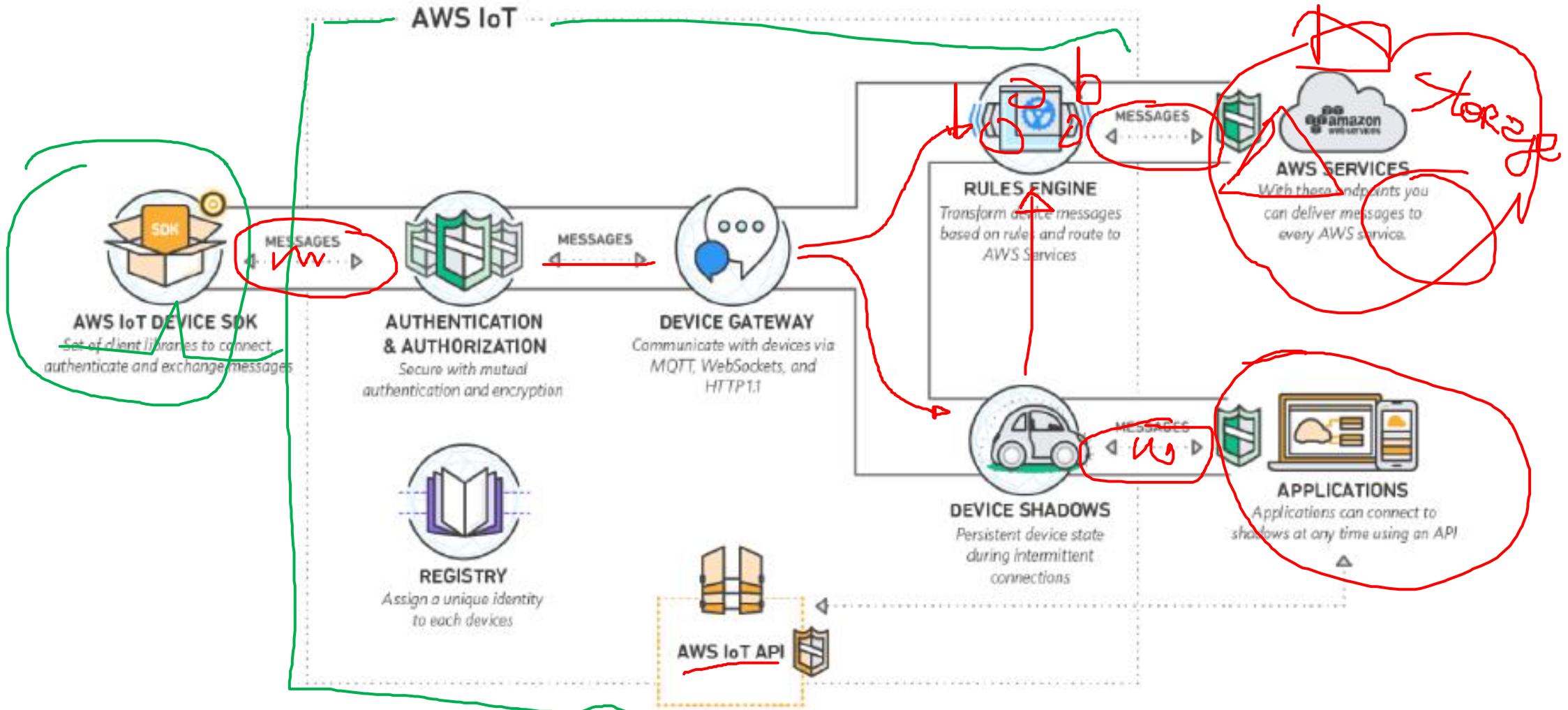
High severity 31 Medium severity 31 Low severity 20

Description	Count	Date	State	Severity
Security incident detected from same source	1	08/26/20	Active	High
Security incident detected	1	08/23/20	Active	High
NEW Suspicious process executed [seen multiple times]	1	08/29/20	Active	High
Potential SQL Injection	2	08/26/20	Active	High
Potential SQL Brute Force attempt	1	08/26/20	Active	High
Attempted logon by a potentially harmful application	1	08/26/20	Active	High
Access from a Tor exit node to a storage file share	2	08/24/20	Active	High
Access from a Tor exit node to a storage blob container	1	08/24/20	Active	High

AWS – Amazon IoT (1)



AWS – Amazon IoT (1)





AWS – Amazon IoT (2)

- Data collected by Rules Engine and Device Shadows. AWS Lambda event-driven, serverless computing platform
- AWS Lambda programming language:
 - Java, Node.js, Python, Go, .NET, Ruby
- MQTT, MQTT over WebSocket, HTTPS
- AWS Cloud Security: TLS, x.509, IAM, Amazon Cognito, Federated Identities, Application Security, regulatory frameworks...

AWS – Amazon IoT (3)



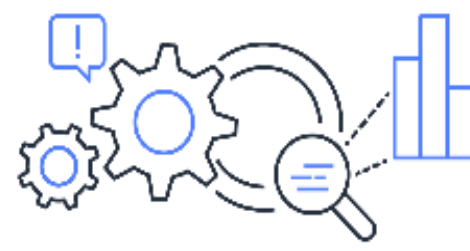
Preveni

Definisci le autorizzazioni e le identità dell'utente, nonché le misure di protezione dell'infrastruttura e dei dati per una strategia di adozione di AWS uniforme e pianificata.



Rileva

Otteni visibilità sul profilo di sicurezza della tua organizzazione con servizi di registrazione e monitoraggio. Inserisci queste informazioni in una piattaforma scalabile per la gestione, il test e l'audit degli eventi.



Rispondi

Risposta agli incidenti e ripristino automatizzati per aiutare a spostare l'attenzione principale dei team di sicurezza dalla risposta all'analisi della causa principale.

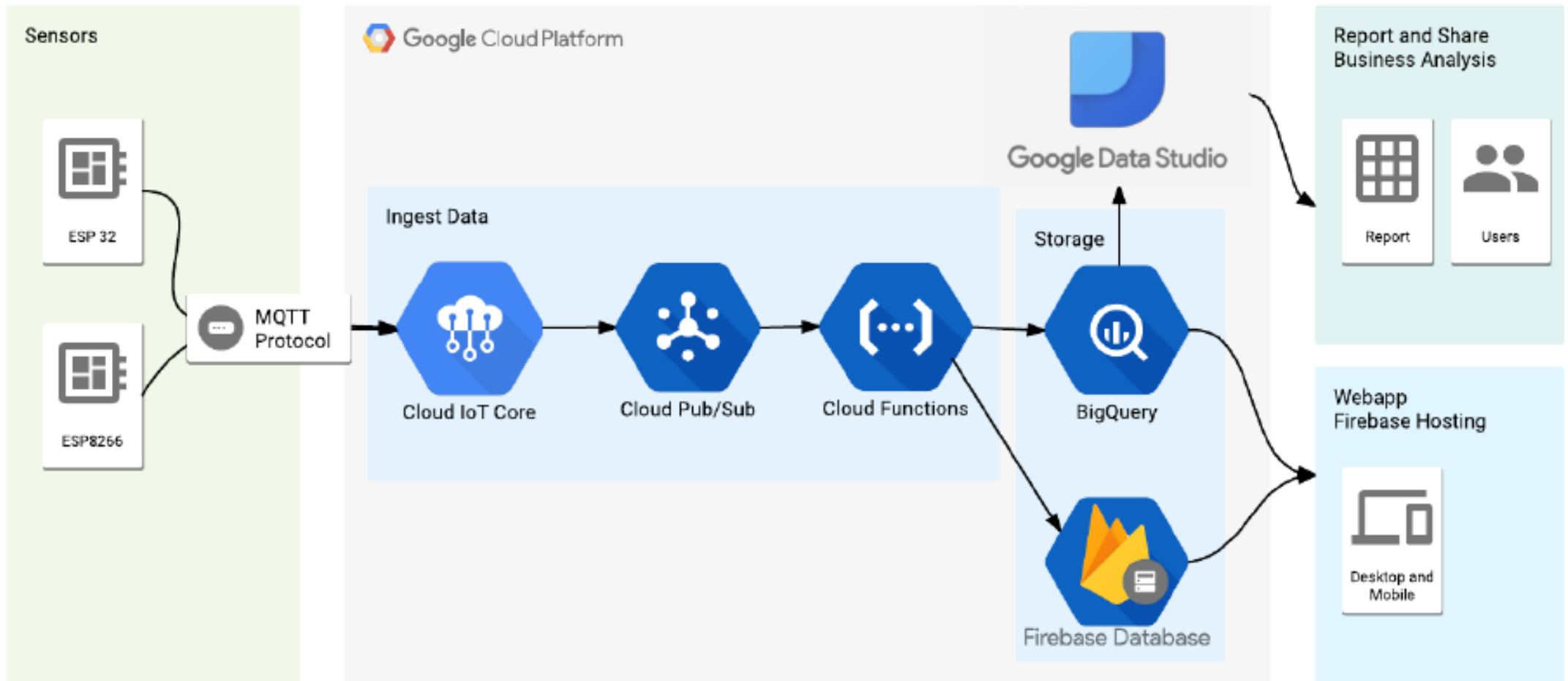


Risolvi

Sfrutta l'automazione guidata dagli eventi per risolvere rapidamente e proteggere il tuo ambiente AWS quasi in tempo reale.



Google IoT (1)





Google IoT (2)

- Cloud IoT Core that communicate with internal functionalities, in a Pub/Sub and Dataflow manner
- Cloud Functions can be written using:
 - JavaScript, Python 3, Go, or Java runtimes
- MQTT, HTTP
- Google Device security: TLS, JSON Token, IAM, x.509, PKI, Key rotation, ...



- Application Security Requirements for IoT Devices

- Security Requirements

1. Best Secure Coding Practices Should be Followed
2. Use of TLS for all Network Communications
3. Verified Firmware Updates
4. Scalable Process for Firmware Updates
5. Strong Authentication Mechanisms
6. Unique MAC Addresses
7. No Communication With third-party Servers
8. No Hardcoded Credentials
9. Unique & Replaceable Certificates
10. Commitment to Security Updates
11. Minimum Service Exposure
12. WiFi Must Use WPA2
13. Bluetooth Security
14. Sync Clocks with NTP
15. No External Network Connectivity
16. Use of Non-WiFi Wireless Interfaces
17. Identification and Delivery of Open Source Components
18. Graceful Degradation
19. Test Resilience

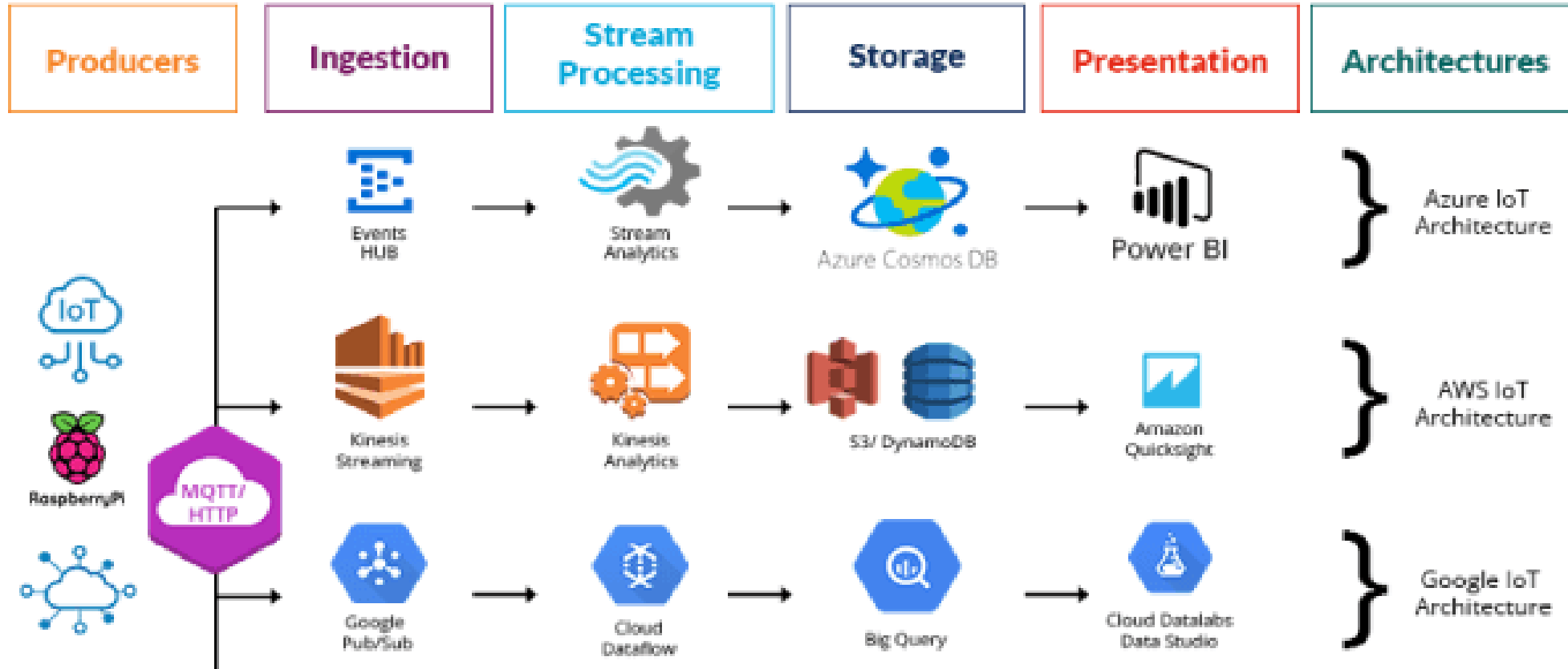
- Recommendations

1. Provide Facilities for Remote Logging
2. IEEE 802.1x Support with Certificates
3. Certificate-Based Mutual Authentication
4. Perfect Forward Secrecy Support
5. IPv6 Support
6. Honor DHCP/IPv6 RA Options
7. Transparent Patch Management

- Guidelines

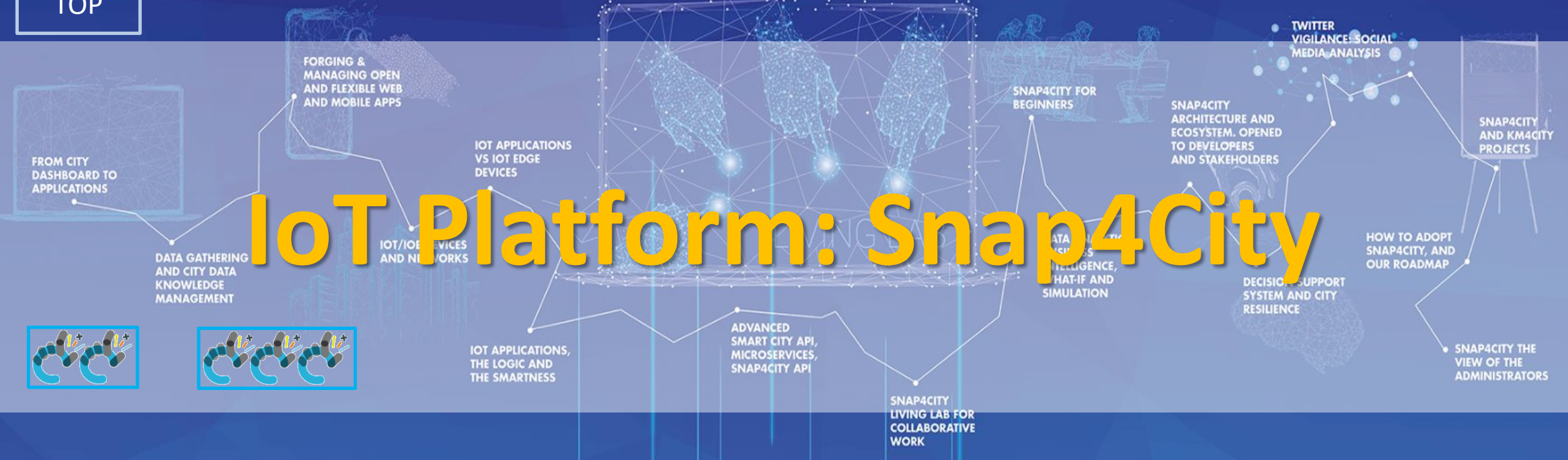
1. IEEE 802.1AR Secure Device Identity
2. Secure/Verified Boot
3. Manufacturer Usage Descriptions

IoT Architectures comparison



TOP

IoT Platform: Snap4City





APPLIANCES CONTAINERS



- LOCAL GOVERN
- STAKEHOLDERS
- CITY USERS
- IN-HOUSE
- ENERGY OPERATORS
- MOBILITY OPERATORS
- COMMERCIAL OPERATORS
- SECURITY OPERATORS
- INDUSTRIES
- RESEARCHERS
- START-UPS
- ASSOCIATIONS

- GDPR
- SECURITY
- PRIVACY
- ASSESSMENT
- AUDITING
- PENTESTED

- OPEN IOT DEVICES
- IOT EDGE
- IOT GATEWAY
- PAX COUNTERS
- IOT BUTTONS

- TEST CASES, SCENARIOS, VIDEOS, HACKATHONS
- OPEN SOURCES, COMMUNITY OF CITIES
- TRAINING TUTORIALS, COMMUNITY MANAGEMENT

IOT APPLICATIONS - INSTANT APPS



DATA DRIVEN APPLICATIONS • REAL TIME PROCESSING • BATCH PROCESSING • ANY PROTOCOL & FORMAT

DASHBOARDS & APPLICATIONS



CONTROL ROOM • SITUATION ROOM • OPERATOR DASHBORDS • BUSINESS INTELLIGENCE • WHAT-IF ANALYSIS • DECISION SUPPORT • SIMULATIONS • RISK ANALYSIS • RESILIENCE ANALYSIS

MOBILE & WEB APPLICATIONS



DEVELOPMENT KIT • SUGGESTIONS • MOBILE APPS • MONITORING PANELS • PLATFORM UTILITIES • READY TO USE SMART APPLICATIONS

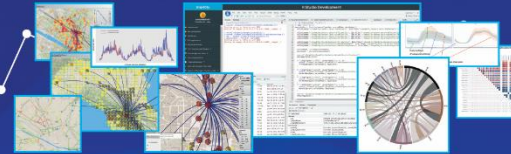
MICROSERVICES & ADVANCED SMART CITY API

LIVING LAB - DEV TOOLS - COWORKING



IOT DIRECTORY • SERVICE MAP • RESOURCE MANAGER • DATA GATE • R STUDIO • ETL

BIG DATA - DATA ANALYTICS



PREDICTIONS • ANOMALY DETECTION • WHAT-IF ANALYSIS • TRAFFIC FLOW RECONSTRUCTION • ORIGIN-DESTINATION MATRICES • SOCIAL MEDIA ANALYSIS • OFFER VS DEMAND ANALYSIS • ENVIRONMENTAL DATA ANALYSIS AND PREDICTIONS • REAL TIME HEATMAPS • ROUTING • ALERTING • EARLY WARNING • PERSONAL AND VIRTUAL ASSISTANTS • SMART SOLUTIONS • SMART SHARING • PARTECIPATORY

DATA ANALYTICS TOOLS - MICRO-APPLICATIONS



KM4CITY DATA AGGREGAT KNOWLEDGE BASE - EXPERT SYSTEM OF THE CITY - BIG DATA STORE

IOT MNG - DATA MNG - DATA INSPECTOR - PROCESS MNG - USER ENGAGEMENT - GDPR MNG ...

- GIS
- CITY UTILITIES
- OPEN DATA
- LEGACY & EXTERNAL SERVICES
- PERSONAL DATA
- IOT / IOE
- BROKERS
- KPI
- INDUSTRY 4.0
- SOCIAL MEDIA



Tools for rapid implementation of sustainable Smart Solutions and Decision Support Systems

www.snap4cityv.org



Powered by **FIWARE**

FREE TRIAL

PEN Test Passed

EU GDPR COMPLIANT

SNAP4 Appliances and Dockers Installations

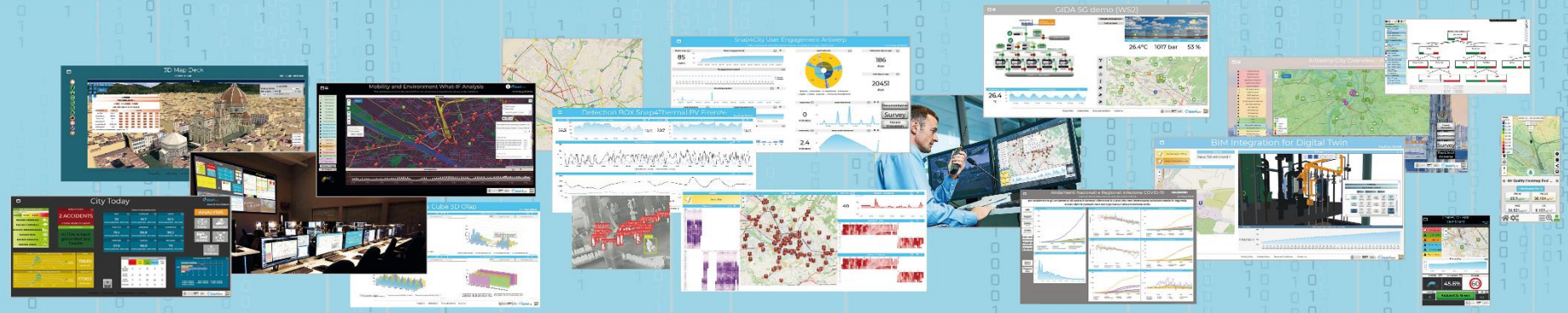
EUROPEAN OPEN SCIENCE CLOUD

Node-RED

JS Foundation

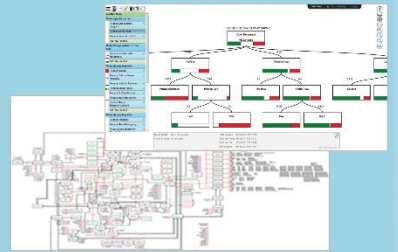
E015 digital ecosystem

NVIDIA



DASHBOARDS AND APPS - CONTROL ROOMS - DECISION SUPPORT SYSTEMS - WHAT-IF ANALYSIS - VISUAL ANALYTICS

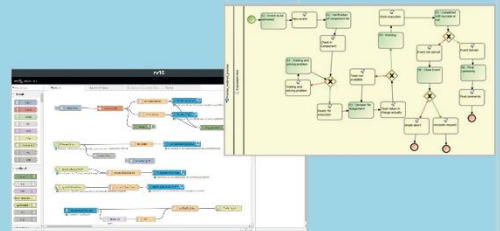
**PREDICTION - ANOMALY DETECTION - ENVIRONMENTAL MODEL - 3D MODEL
KPI - SIMULATION - EARLY WARNING - SYNOPTIC - DIGITAL TWIN - VIRTUAL REALITY**



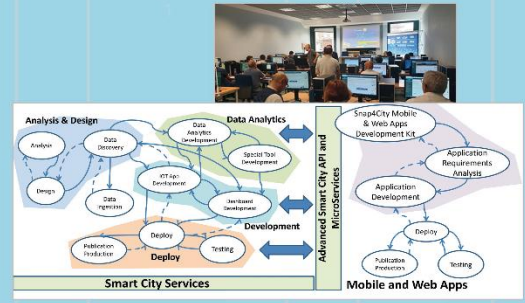
**EXPERT SYSTEM
KNOWLEDGE BASE
STORAGE**



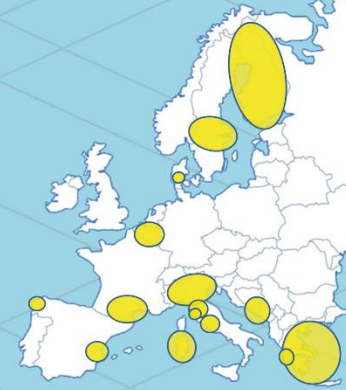
**BIG DATA ANALYTICS
EXPLAINABLE ARTIFICIAL INTELLIGENCE
BUSINESS INTELLIGENCE
MACHINE LEARNING**



**DATA FLOWS, DATA DRIVEN
WORKFLOWS, MICROSERVICES
PARALLEL DISTRIBUTED PROCESSING**



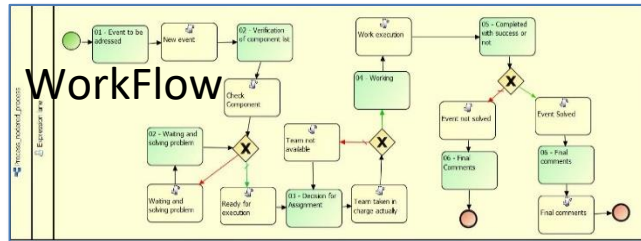
**METHODOLOGIES
LIVING LABS
COURSES AND COMMUNITY
DEVELOPMENT TOOLS**



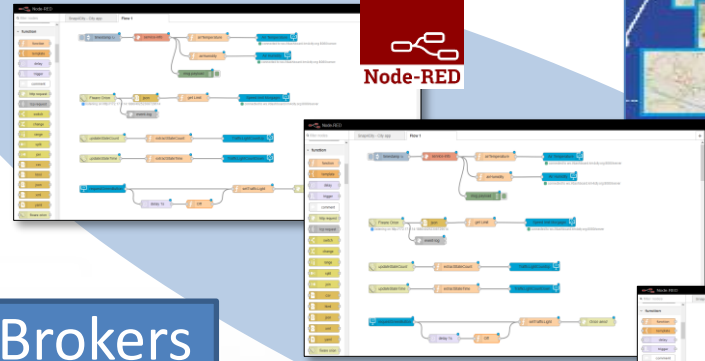
Concept



KPI, POI, MyKPI, ...
API, External Services
Web Scraping



Artwerp City Overview - AS
GIDA 5G demo
13.7 °C 1019 bar 77 %
Air Quality
My Data Dashboard Kibana
7,642,593

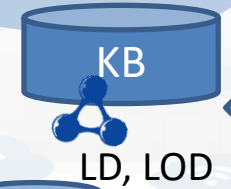


Data Analytics,
Artificial Intelligence



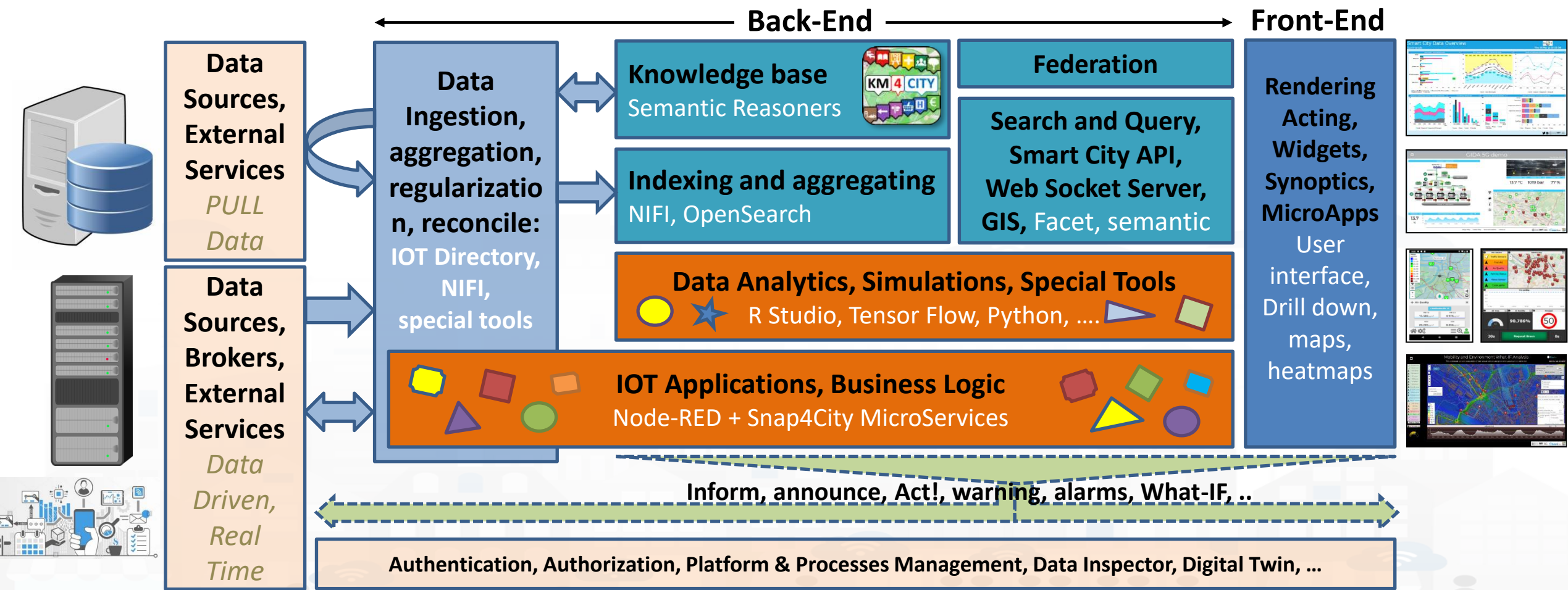
IOT Brokers
IOT Broker
IOT Broker

IOT Apps



Dashboards and Apps

Snap4City, Snap4Industry Architecture, V2



Smart City Functional Architecture

Transport systems
Mobility, parking



Public Services,
Govern, events, ...



Sensors, IOT Cameras,
Wi-Fi



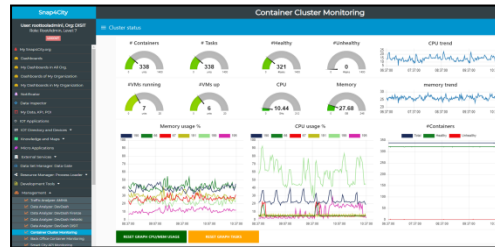
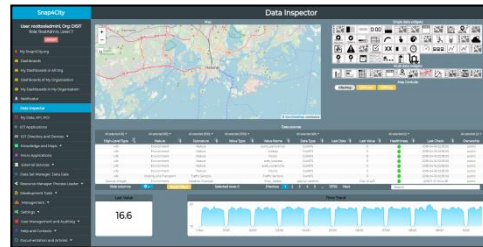
Environment, Water,
energy



Shops, services,
operators

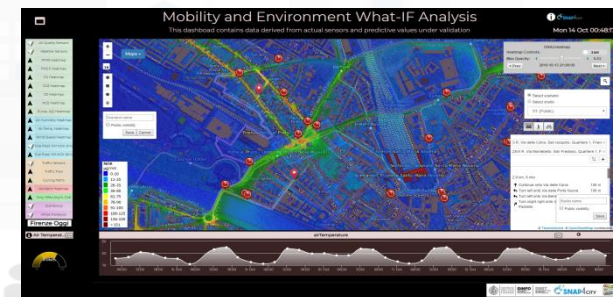
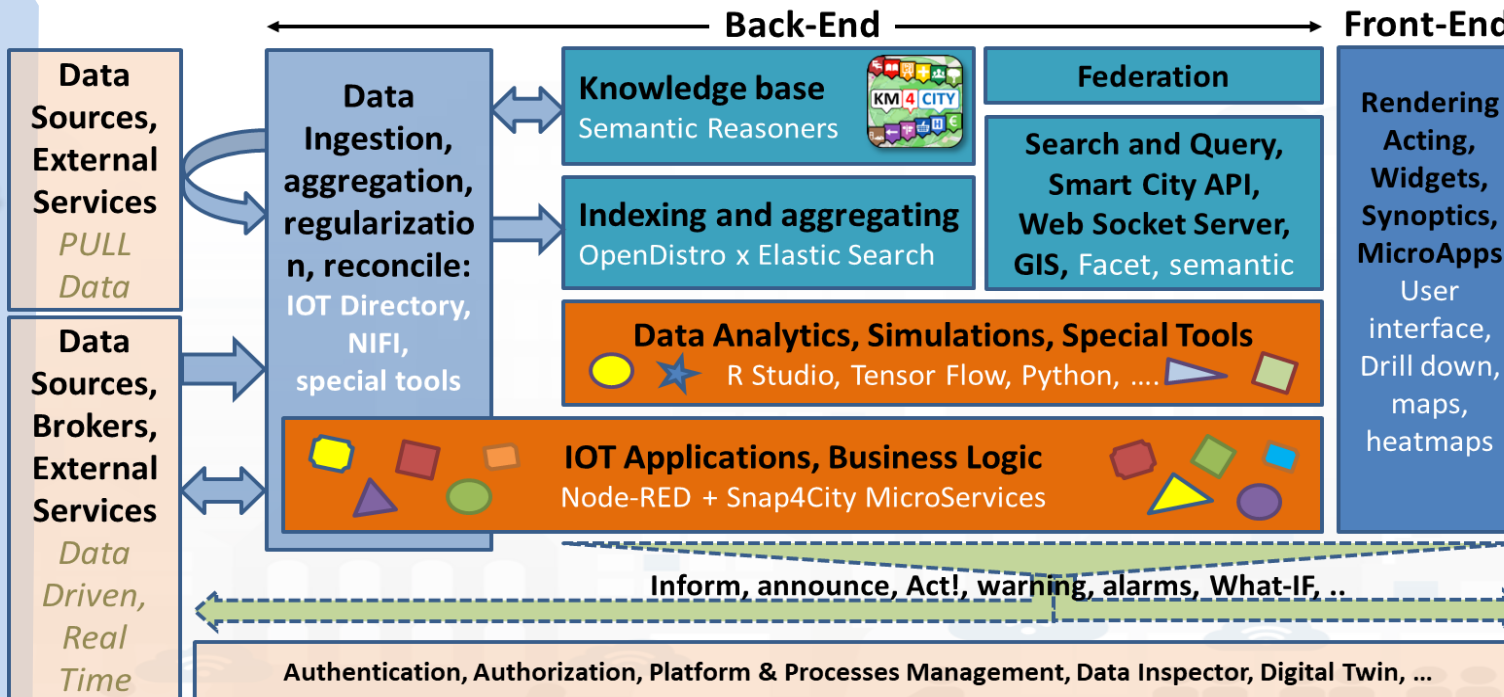
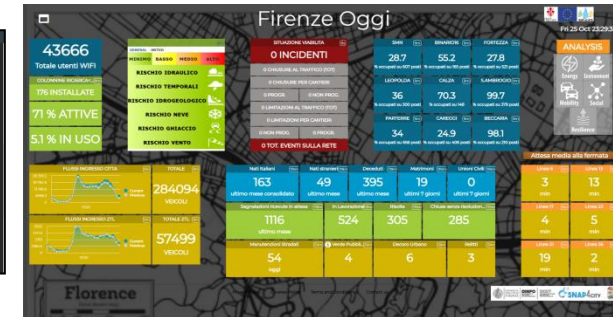


Social Media

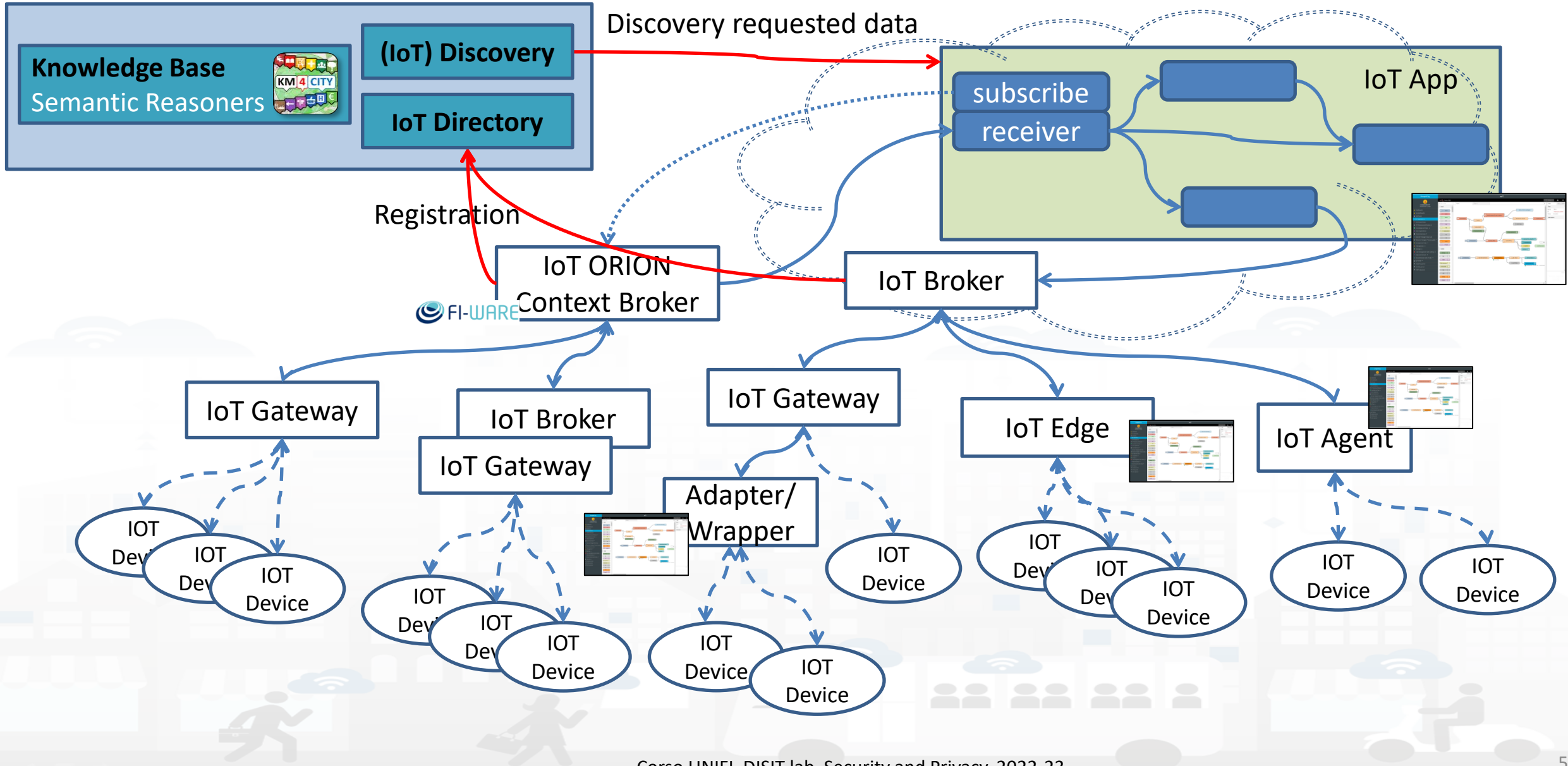


Back office tool

Dashboards, visual tools,
Web and Mobile Apps



IoT Network





IoT main components

- IoT Device
- IoT Router (with/without computation capabilities)
- IoT Broker (+ Shadowing)
- IoT Device Directory
- IoT User Management
- IoT Service Bus (Pub/Sub, Rule-engine, Data-driven)
- IoT Analytics
- IoT Data repository
- IoT Applications (off-grid/on-cloud)
- IoT Dashboards

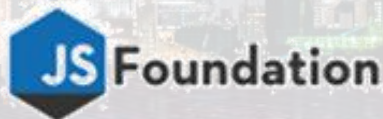
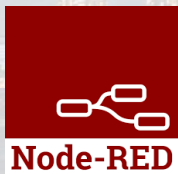
Standards and Interoperability (5/2022)



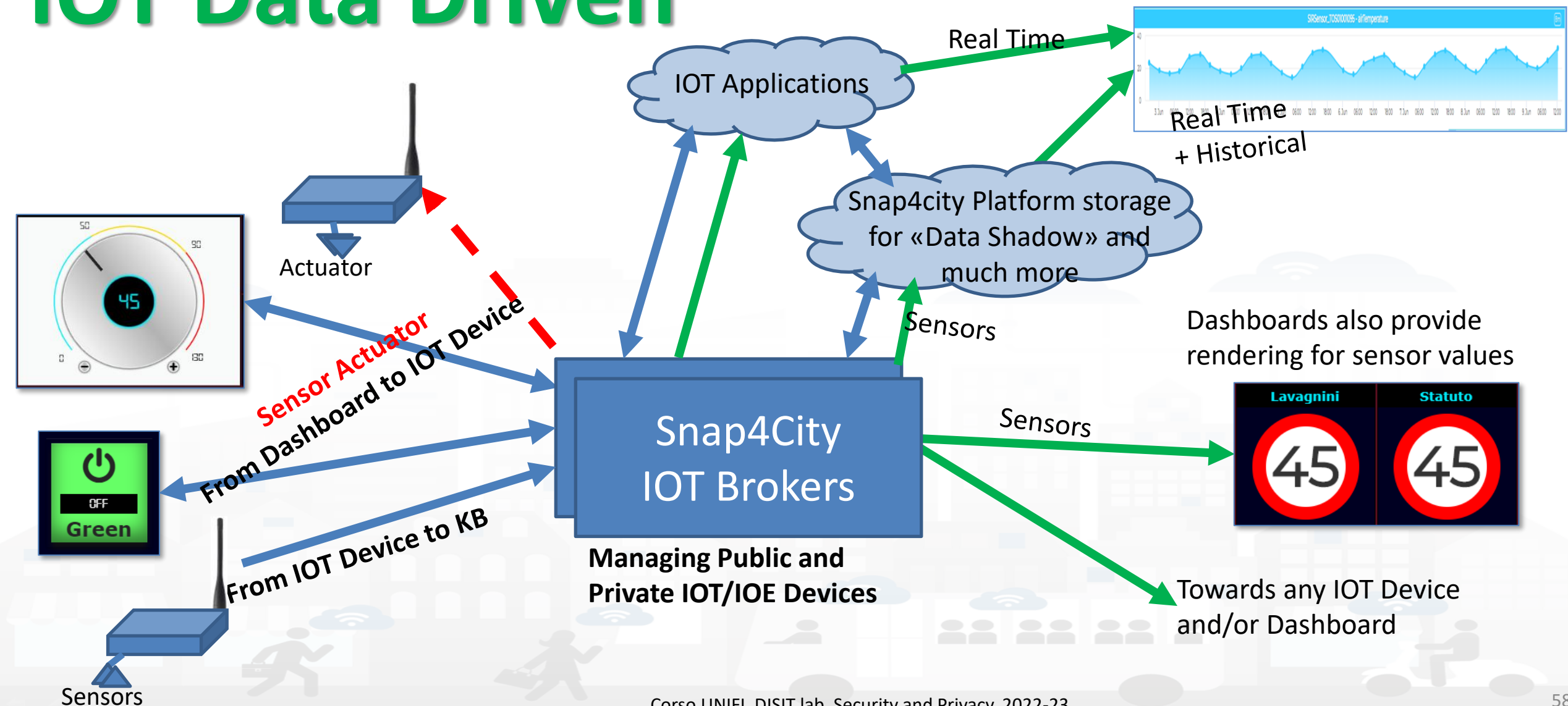
Compliant with:

- **IOT:** NGSI V2/LD, LoRa, LoRaWan, MQTT, AMQP, COAP, OneM2M, TheThingsNetwork, SigFOX, Libelium, IBIMET/IBE, Enocean, Zigbee, DALI, ISEMC, Alexa, Sonoff, HUE Philips, Tplink, BACnet, TALQ, Protocol Buffer, KNX, ..
- **General:** HTTP, HTTPS, TLS, Rest Call, SMTP, TCP, UDP, SOAP, WSDL, FTP, FTPS, WebSocket, WebSocket Secure, GML, WFS, WMS, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP,
- **Formats:** JSON, GeoJSON, XML, CSV, GeoTIFF, OWL, WKT, KML, SHP, db, XLS, XLSX, TXT, HTML, CSS, SVG, IFC, XPD, OSM, Enfuser FMI, ...
- **Database:** Open Search, MySQL, Mongo, HBASE, SOLR, SPARQL, ODBC, JDBC, Elastic Search, Phoenix, OBD2, PostGres, MS Azure, ..
- **Industry:** OPC/OPC-UA, OLAP, ModBUS, RS485, RS232,...
- **Mobility:** DATEX, GTFS, Transmodel, ETSI, ..
- **Social:** Twitter, FaceBook, Telegram, ..
- **Events:** SMS, EMAIL, CAP, RSS Feed, ..
- **OS:** Linux, Windows, Android, Raspberry Pi, Local File System, ESP32, etc.

<https://www.snap4city.org/65>



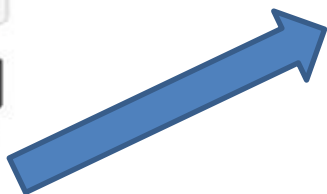
IOT Data Driven



IoT Devices



IoT Device Models



IoT Device

- Name:.....
- Model:.....
- Position:

IoT Device Variables

- **dateObserved:**
- ID:
- Status: ready
- Temperature: 70%
- WaterLevel: 35%
- UsedCapsBox: 30%
- Power: OK
-

- Conceptually are IoT Devices with sensors/actuators, IN/IN-OUT

- They are classified in terms of nature/subnature

- For Searching and showing on maps and dashboards

HLT of IoT Devices can be:

- **IoT Device Models**, for example: «personal coffee machine»
- **IoT Device name**, for example: «mycoffemachine1», «CM23»
- **IoT Device Variable**, for example: «Temperature»





Mobile Device Models



Mobile Device

- Name:.....
- Model:.....
- Spec:...

Mobile Device Variables

- ID:
- **dateObserved:**
- Status: ready
- Temperature: 70%
- Gasoline: 35%
- Velocity: 231,3 Km/h
- **Position: 44.3223, 11.3432**
-

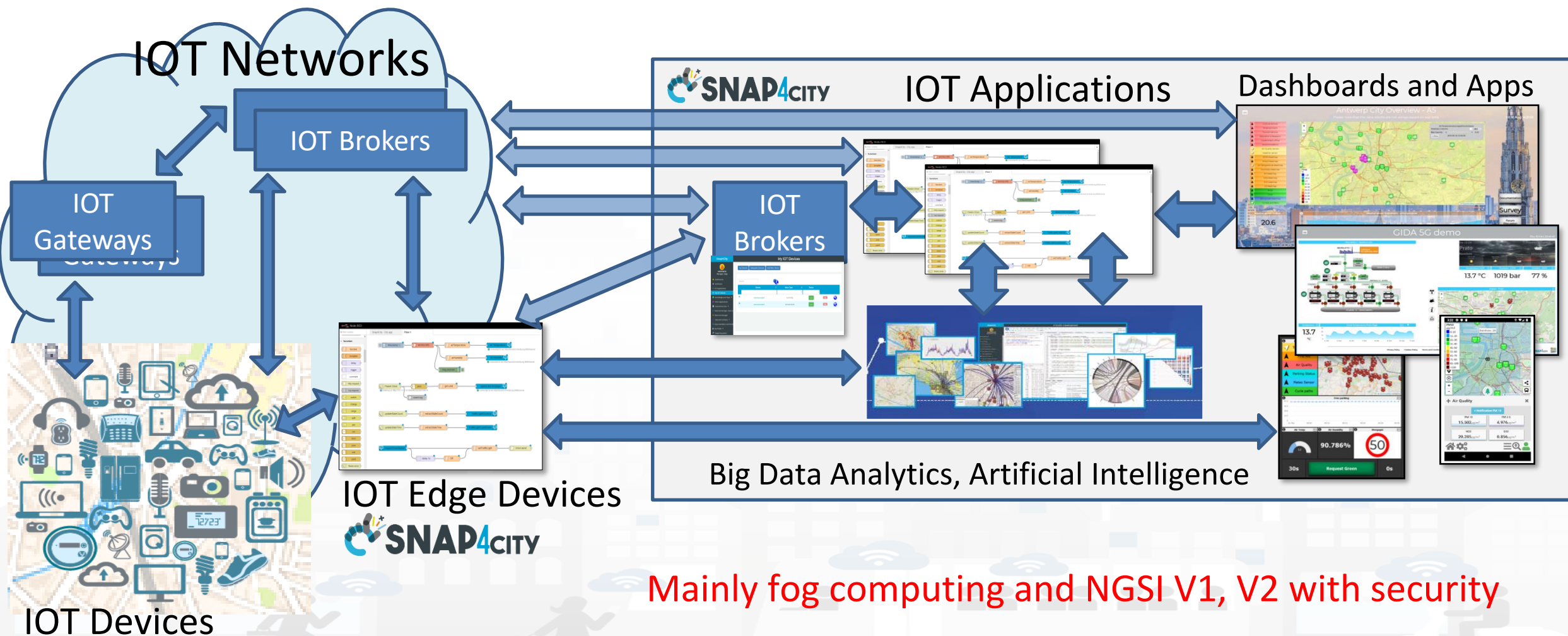
- They are a special case of IoT Devices
 - they are managed as IoT Devices in the system
- They are classified in terms of nature/subnature
- For Searching and showing on maps and dashboards, they are different

HLT of Mobile Devices can be:

- **Mobile Device Model**, for example: «sedan»
- **Mobile Device name**, for example: «BMW JD7356HD», «Ford KO786KK»
- **Mobile Device Variable**, for example: «velocity»

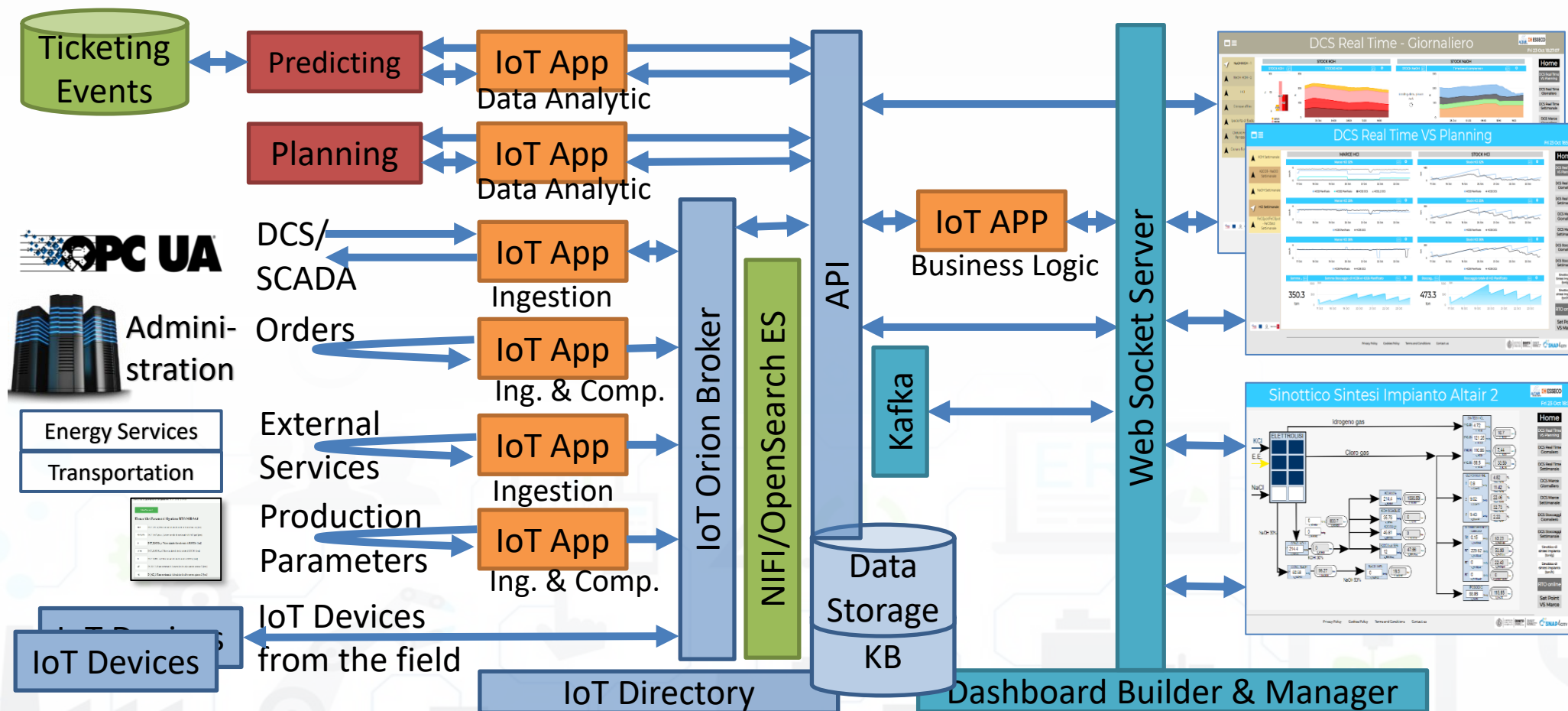


Snap4City Services also on IOT Edge!!!



Mainly fog computing and NGSI V1, V2 with security

Snap4Industry IOT Architecture

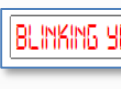
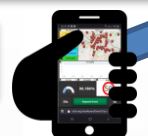
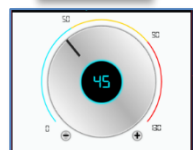
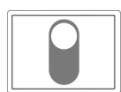


Dashboard-IOT App



PeopleNumber		
line	Last confirmed	
	None	
7	8	9
4	5	6
1	2	3
0	.	Cancel

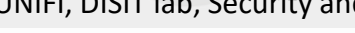
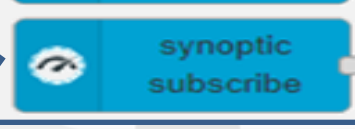
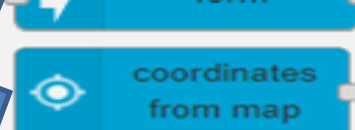
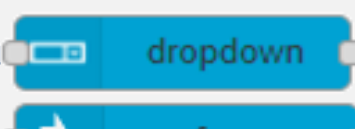
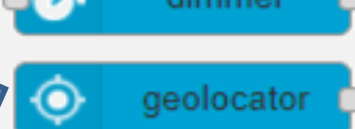
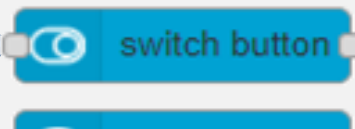
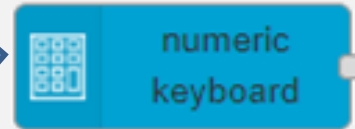
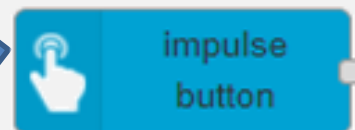
Confirm



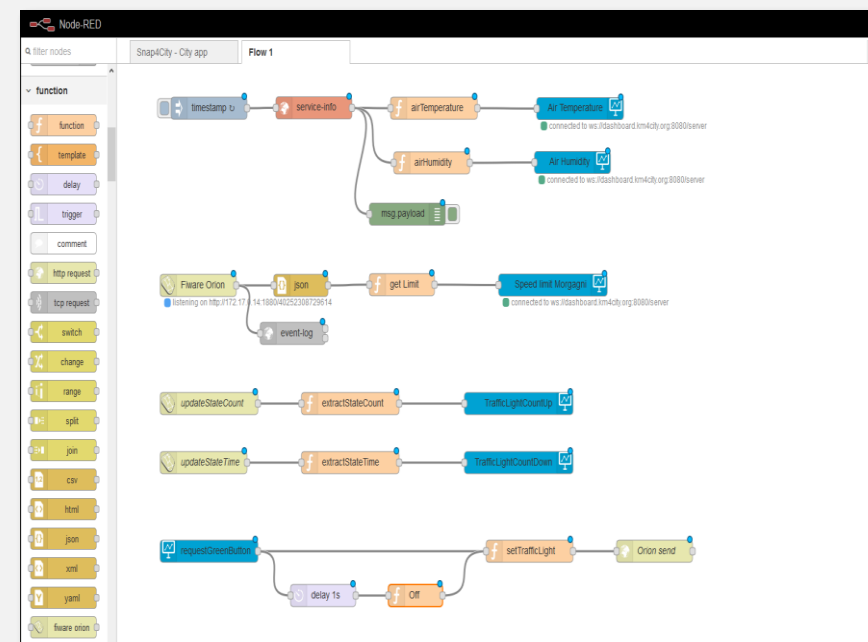
MapClick

MyKPI variable onchange

Synoptics



From Dashboard to IOT App



IOT Application

Dashboard-IOT App

From IOT App to Dashboard

- gauge chart
- single content
- speedometer
- horizontal single bar
- vertical single bar
- web content
- time trend
- bar series
- radar series
- pie chart
- curved line series
- table content
- calendar
- speak synthesis
- synoptic write
- Selector - Map

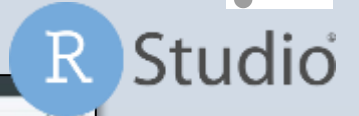
IOT Application

sensor name	airHumidity	airTemperature	PM2_5	PM10	O3
IBNET_SMART3 - PM2.5	59.8	17.0	225.26	225.26	0.14
IBNET_SMART3 - PM10	48	13.3	97.96	107.25	0.16
IBNET_SMART3 - O3	56.2	13.4	0	300	0.17
IBNET_SMART3 - PM2.5	57.5	16.3	16.47	16.33	0.16
IBNET_SMART3 - PM10	64	16.2	53.33	61.1	0.15
IBNET_SMART3 - O3	6	21.9	3.7	3.47	0.14
IBNET_SMART3 - PM2.5	51.1	9.1	13.03	5.81	0.12

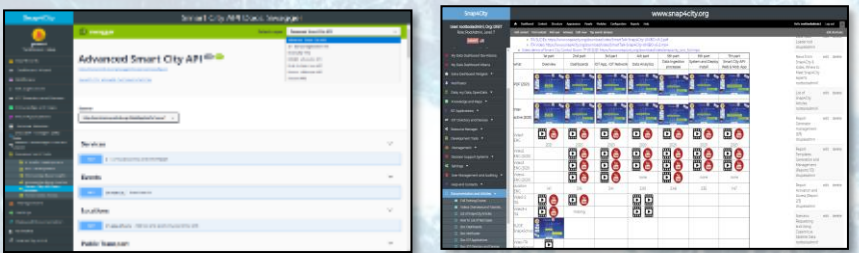
Widgets ICONS	Widget Name, Description	IOT App	Dashboard-IOT App	KPI (metric)	MyPersonalID ata	MyData ta	My KPI	Sensor
	Single Content	X (cs)	X (DD)	X	X	X	X	X
	Speed Limit (see custom widget for more)			X				X
	Speedometer	X (cs)	X (DD)	X	X	X	X	X
	Gauge	X (cs)	X (DD)	X	X	X	X	X
	Single Bar, V/H	X	X (DD)	X				
	Single and Multiple Bars, stacked or not, ordered	X (cs)	X (DD)	X	X	X	X	X
	MultiSeries, shaded, staked and non staked, TTT	X (cs)	X (DD)	X	X	X	X	X
	Time Trend (single)	X	X (DD)	X	X	X	X	X
	Time Trend Compare			X			X	X
	SpiderNet, radar, Kiviati	X (cs)	X (DD)	X	X	X	X	X
	Pie, Donut, 2 layers Donut	X (cs)	X (DD)	X	X	X	X	X
	Table	X (cs)	X (DD)	X	X	X	X	X
	Calendar	X (cs)	X (DD)				X	X
	Speak Synthesis	X (cs)	X (DD)				string	string
	Maps	X (cs)	X (DD)	Many High Level Types			X	X

DD: Data Driven

Data Analytics on Snap4City platform



Swagger



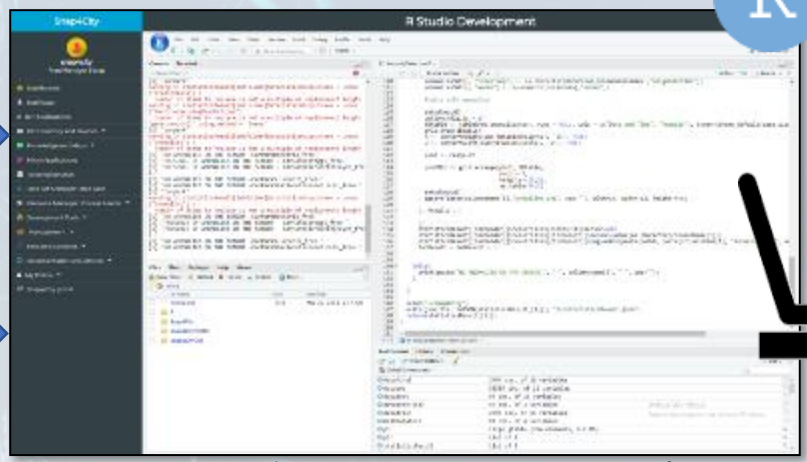
Ontology Schema



LOG.disit.org



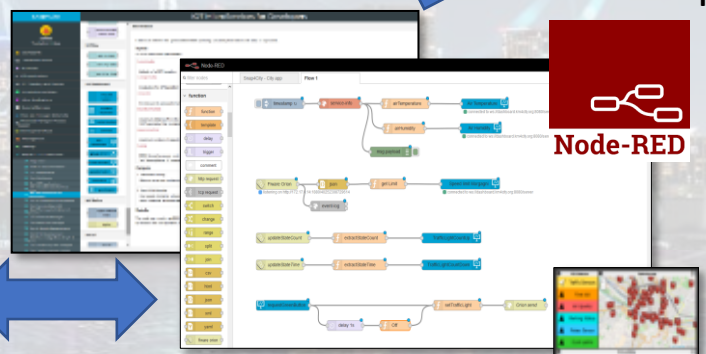
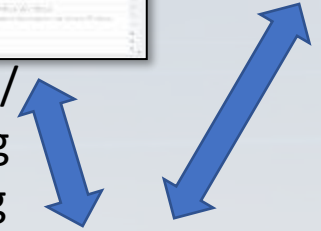
Smart City API from Knowledge Base and other tools



Creating MicroServices



Saving / Sharing reusing



Using them into IOT Applications



Resource Manager



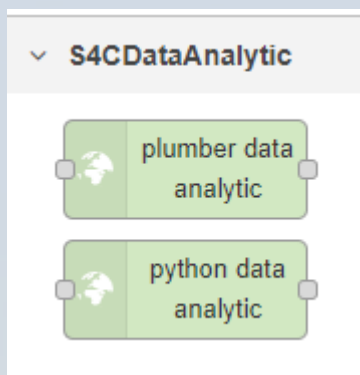


Data Analytic Container



2

Open an advanced IoT App / Node-RED



3

Use Snap4City Data Analytic Node, and load in the code you developed

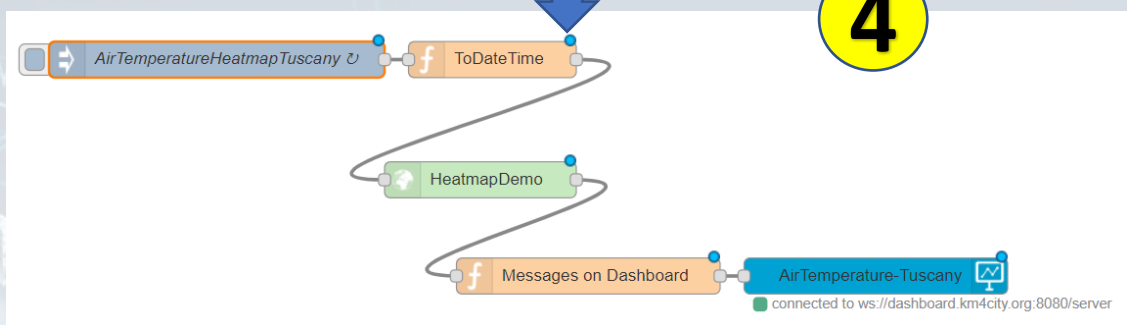
1

Develop .py or .r program on (i) Snap4City platform online, or (ii) your Development Machine.

The code has to respect the guidelines provided. For examples see:

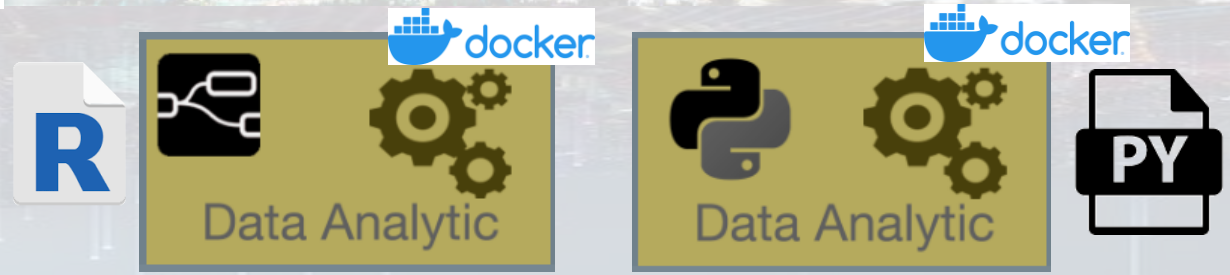
- <https://www.snap4city.org/641>
- <https://www.snap4city.org/645>

4



5

Deploy the IoT App → Snap4City Container Manager based on Marathon/Mesos is creating a Container for your Data Analytic code



Presentation: Control Room, Dashboards, Synoptics, Wizards, Widgets, Visual Analytics Applications, Mobile Apps
Telegram, Bot, ...



External Interoperability: Smart City API, general API and accounting



Operation:

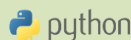
Reporting

Simulation

Heatmapping

Traffic Flows

Tip. Time Trend



Analysis

WorkFlow
Tickets BPM

Sentiment
Analysis

Open to any module and system

Data
Analytics

Predic
tions

Anomaly
detection

Statis
tics

Artificial
Intelligence

Routing



Internal Interoperability: API, MicroServices



Data Management: data modeling, data storage, noSQL,
semantic modeling, city entities, aggregation, normalization, knowledge base



NGSI V1, V2



Linked Data triples

Data Collection: data mining, harvesting, integration,
transformation, data models,



Any protocol and format

Any protocol and format

Connectivity: wired, wireless (Lora, 5G, 4G, 3G, Wi-Fi, etc...), IoT Edge, etc.

Any protocol and format

Any protocol and format



Device Layer



External Third Party Services

Platform Management:
IoT Applications
Data Flow Logic

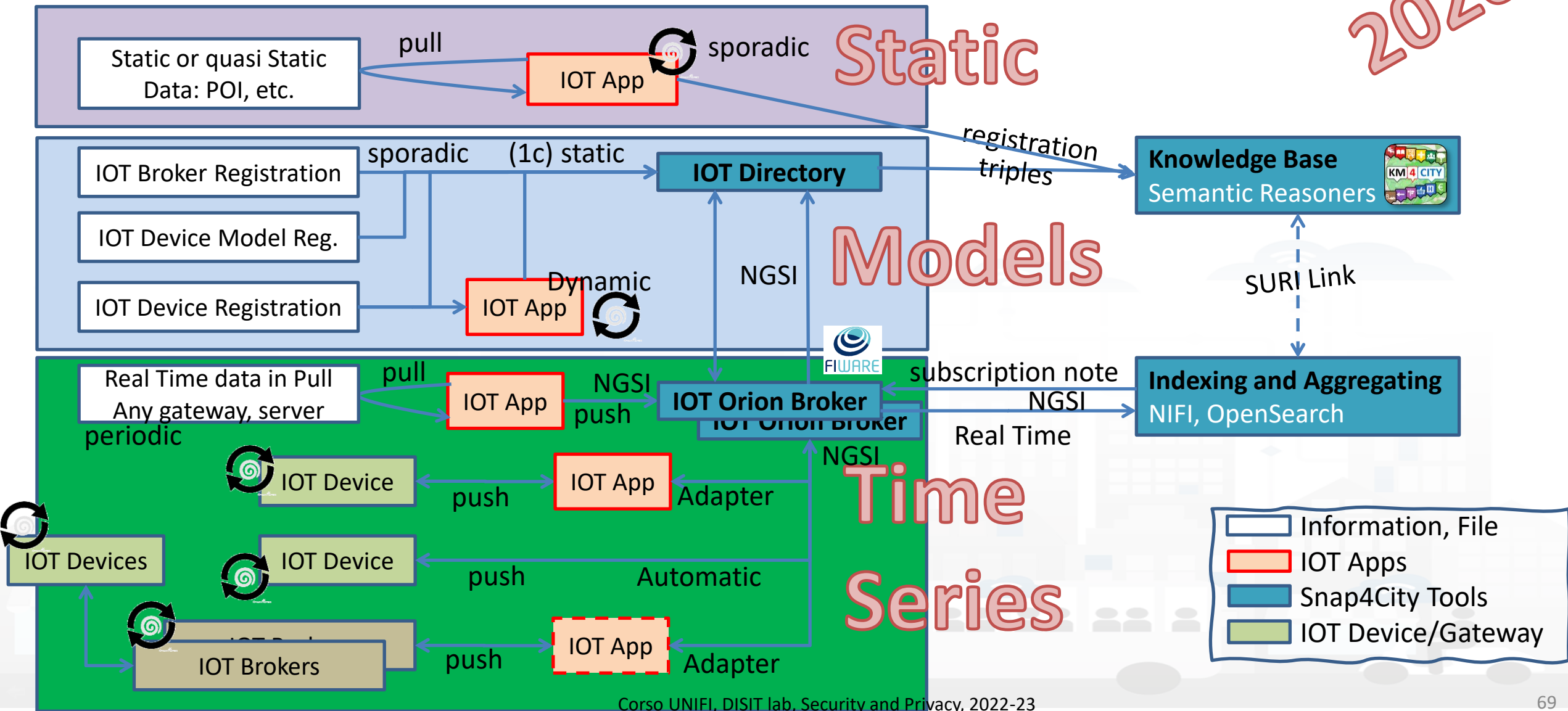


Authentication and Authorization:
GDPR compliant

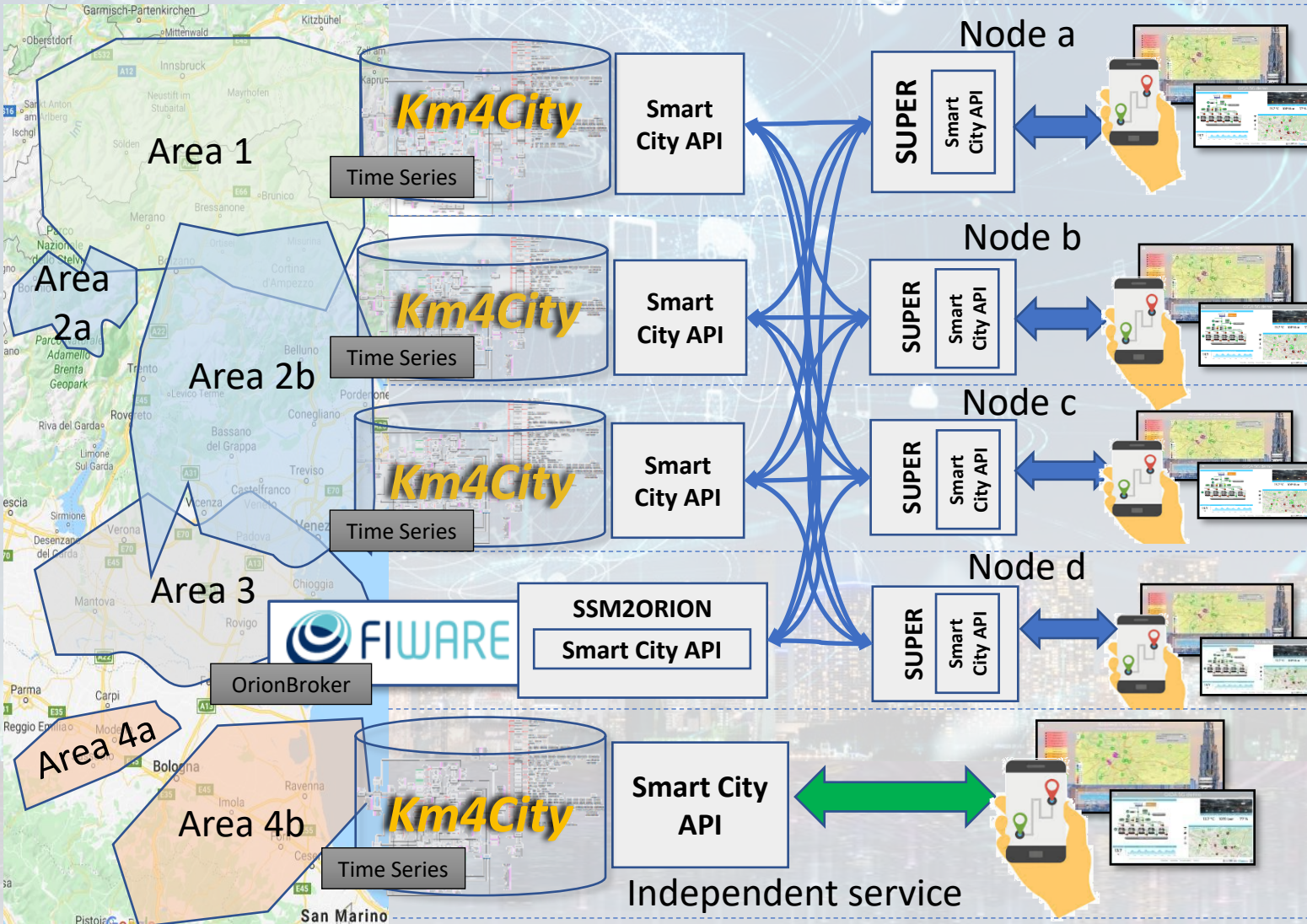


Snap4city Data Ingestion Flow Diagram

2020

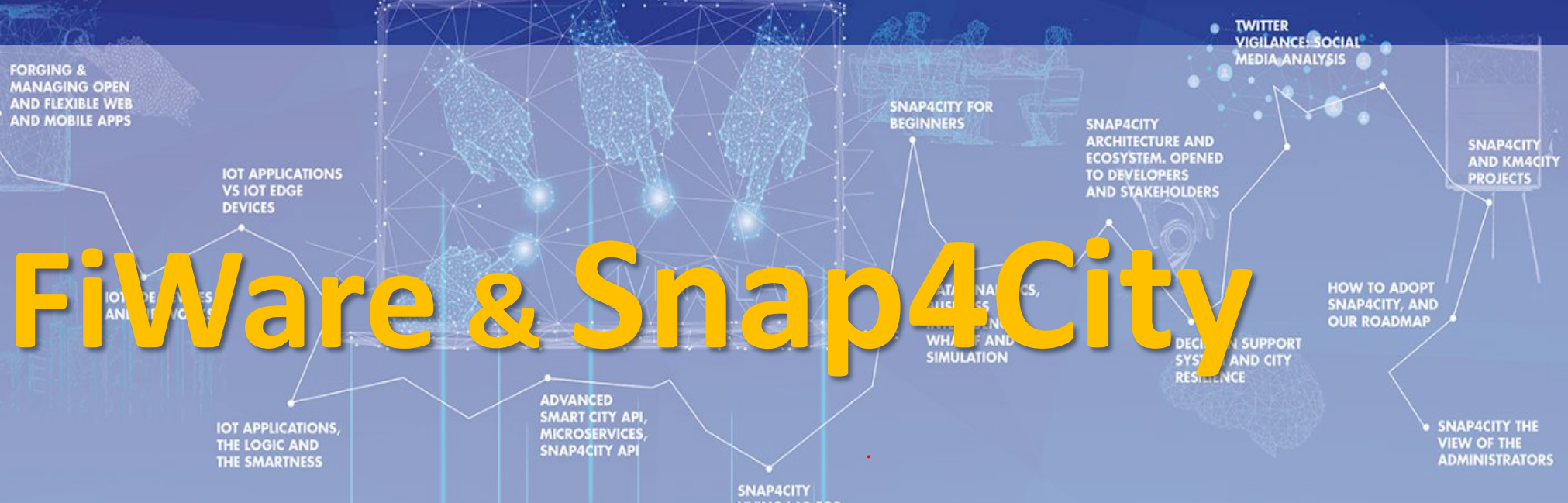


Federation of Smart City Services



- **Km4City Semantic Reasoner**
- **ServiceMap interoperability**
- **Seamless for multiple Mobile Apps**
- **Smart City API**
- **Super:**
 - distributed access and sharing services
 - Each city control its own data
 - Final user can pass from one city / area to another in seamless manner: without changing the mobile Apps

TOP

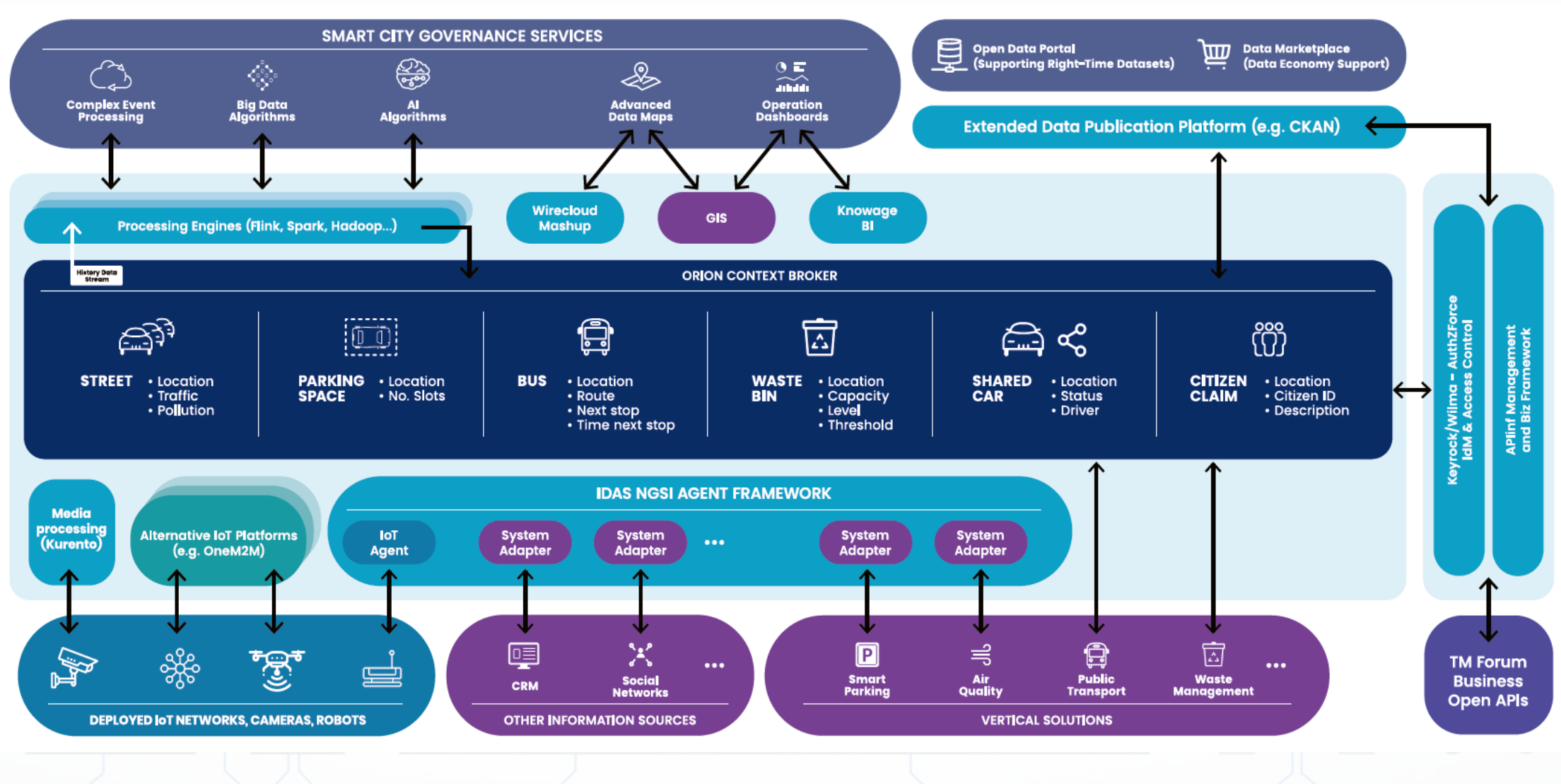


Powered by



FIWARE

>>> THE FIWARE SMART CITIES REFERENCE ARCHITECTURE



- Snap4City - Powered by [FIWARE](#) Solution & Platform:
 - <https://marketplace.fiware.org/pages/solutions/b8905e91973b420189cce972>
 - <https://marketplace.fiware.org/pages/solutions/d68534ec827500f1bde8720f>
 - NGSI V1, V2 The IOT Orion Broker
 - IOT Orion Broker can connect JSON, MQTT, Lightweight M2M, LoraWAN, OPC, SigFOX, etc. see FiWare <https://www.fiware.org>
- Snap4City - [FIWARE](#) Training Services:
 - <https://marketplace.fiware.org/pages/solutions/03bccd83a0e1b0398ba7a0bf>
- Snap4City - [FIWARE](#) Consultancy Services:
 - <https://marketplace.fiware.org/pages/solutions/907f5ecc63927f643dd8421b>
- **Snap4City is compatible** with all the above protocols
 - via IOT Orion Broker,
 - via IOT Applications.
 - via direct connection on ETL processes on their corresponding IOT brokers, and/or
- **Snap4City is also compatible** with many other protocols, see the table reported in page: <https://www.snap4city.org/65>



SMART CITIES AND SMART INDUSTRY

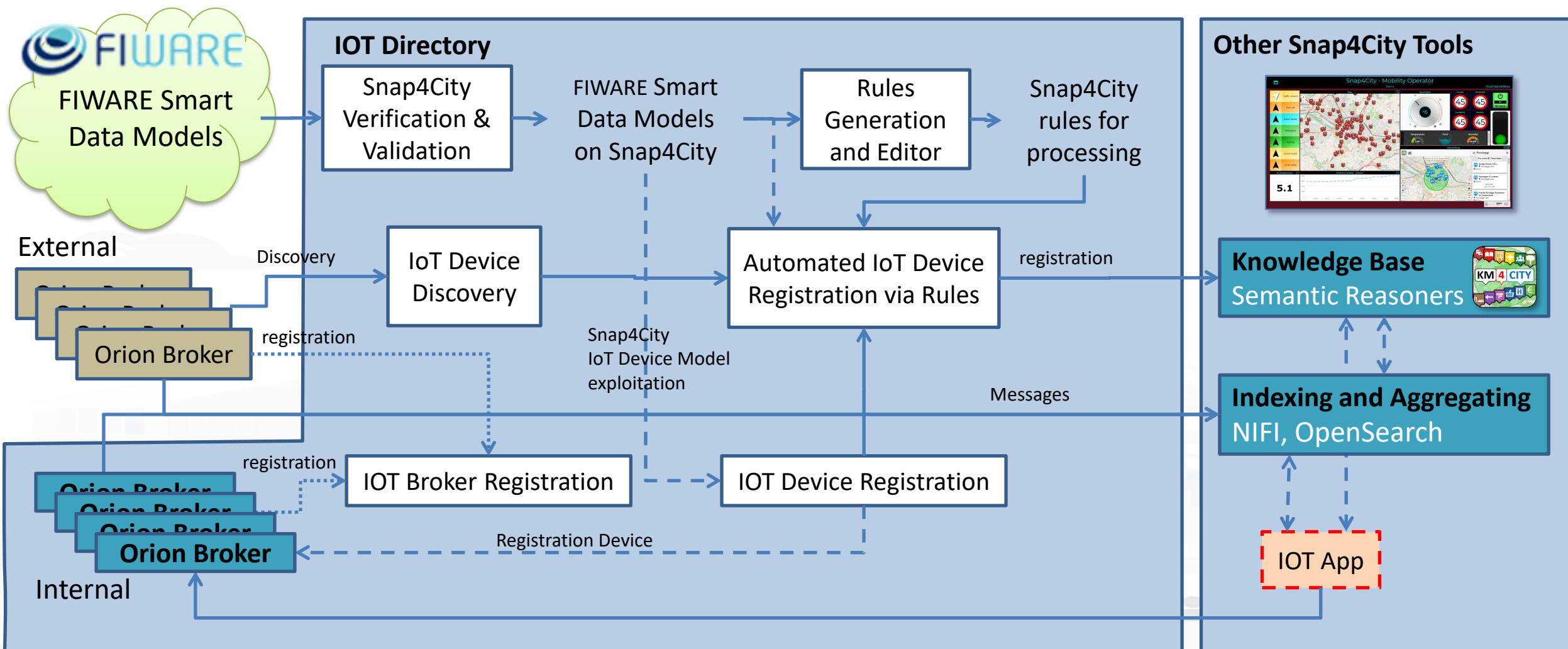
Snap4City:
FIWARE powered smart app
builder for sentient cities

With the contribution of

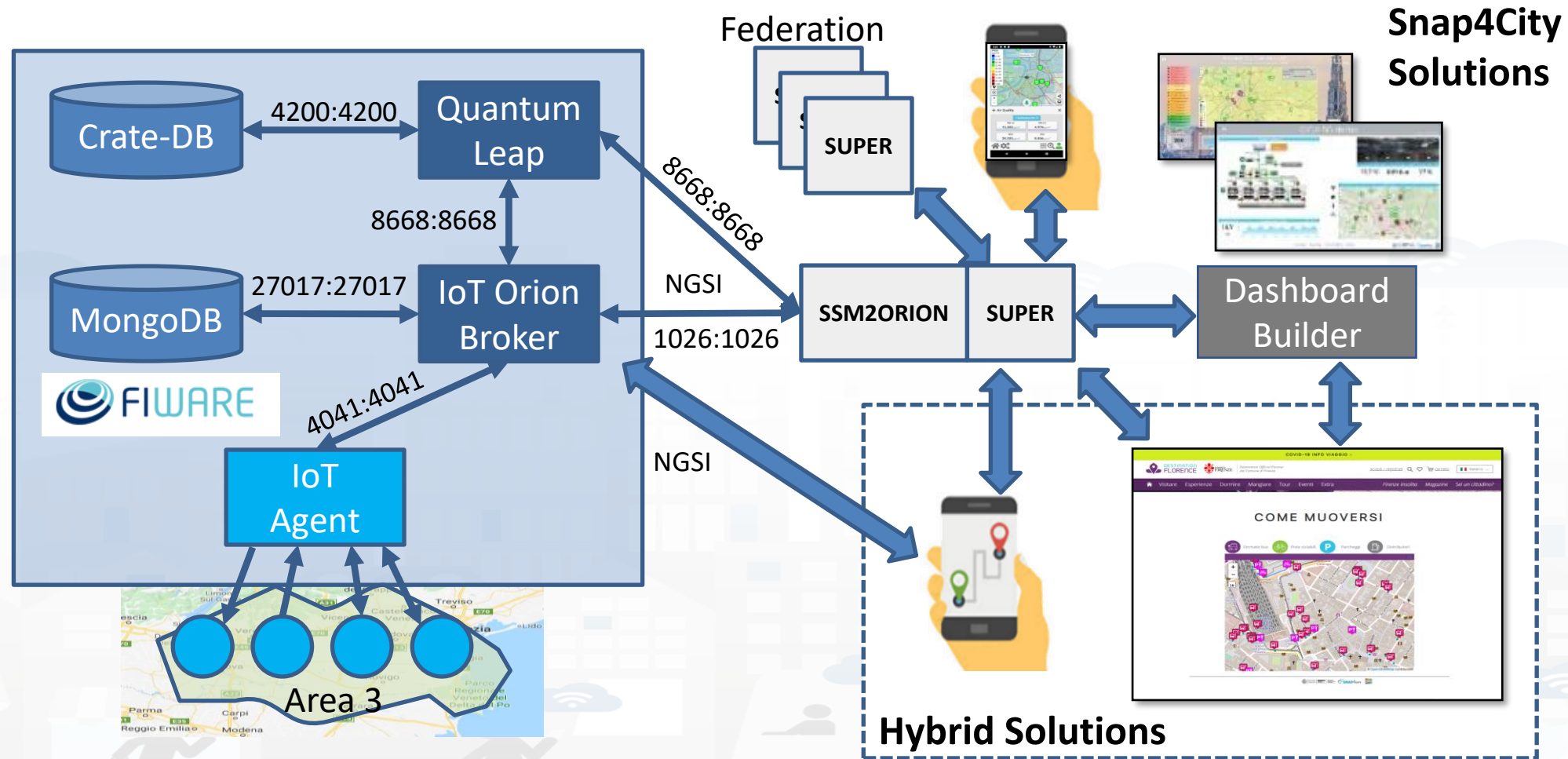


- <https://fiware-foundation.medium.com/snap4city-fiware-powered-smart-app-builder-for-sentient-cities-acfe24df49d5>
- https://www.snap4city.org/download/sites/default/files/files/FF_ImpactStories_Snap4City.pdf

Exploiting FIWARE Smart Data Models

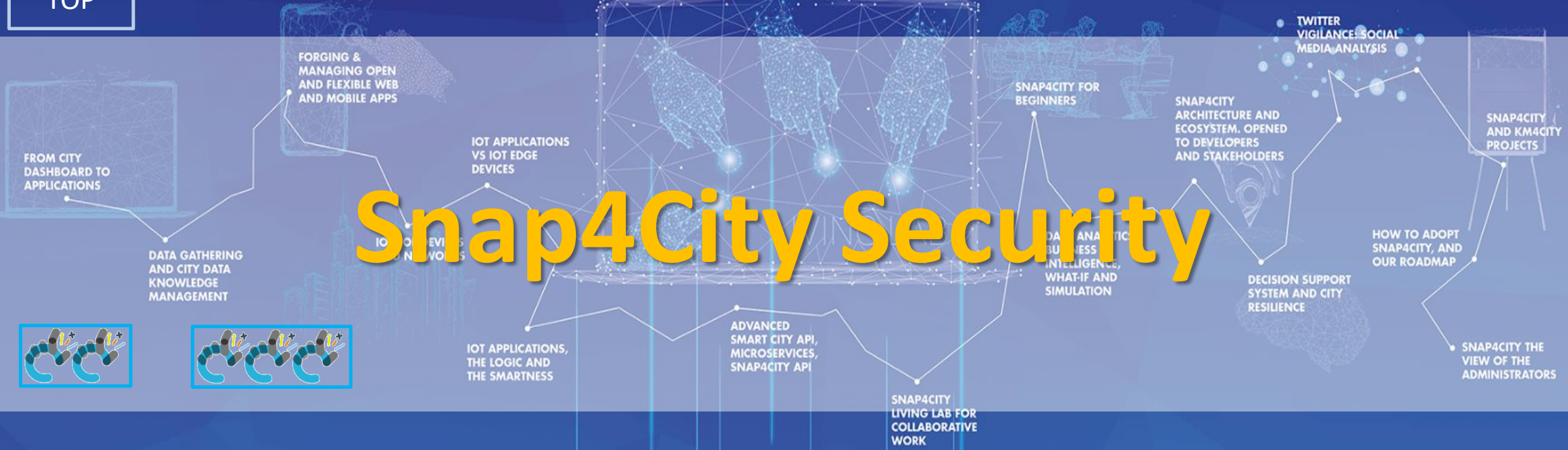


Federation of Snap4City vs IOT ORION Broker



TOP

Snap4City Security

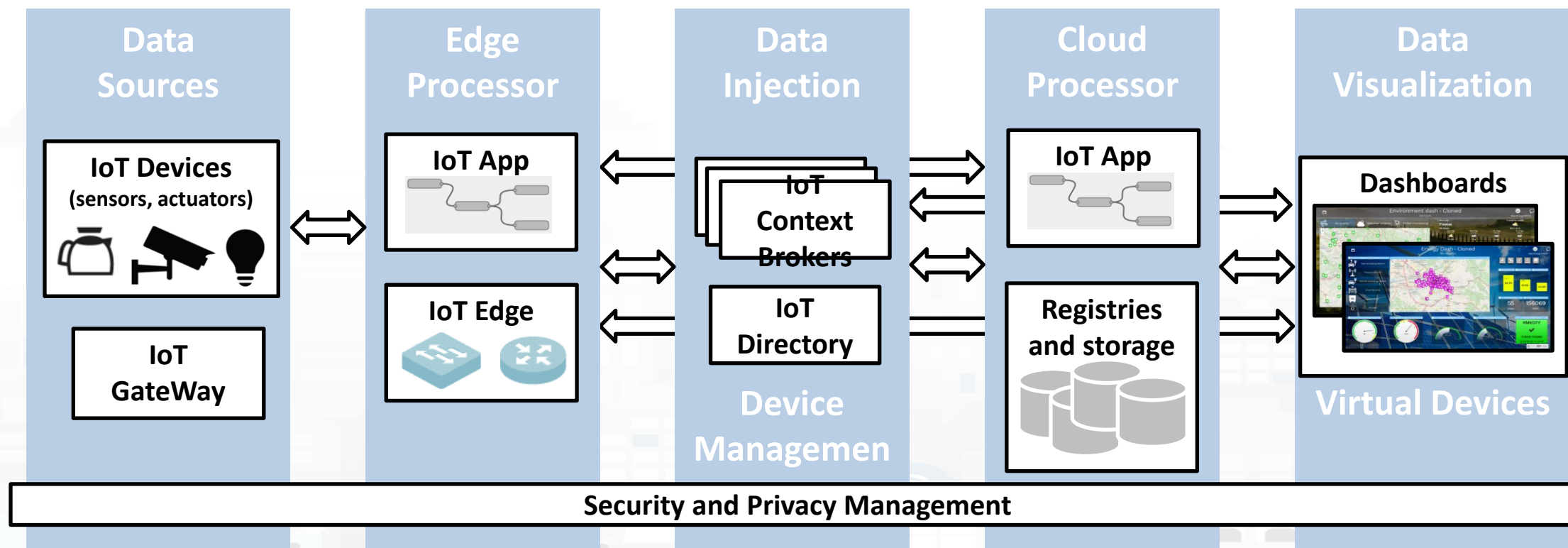


Complexity in Smart City IOT Platforms

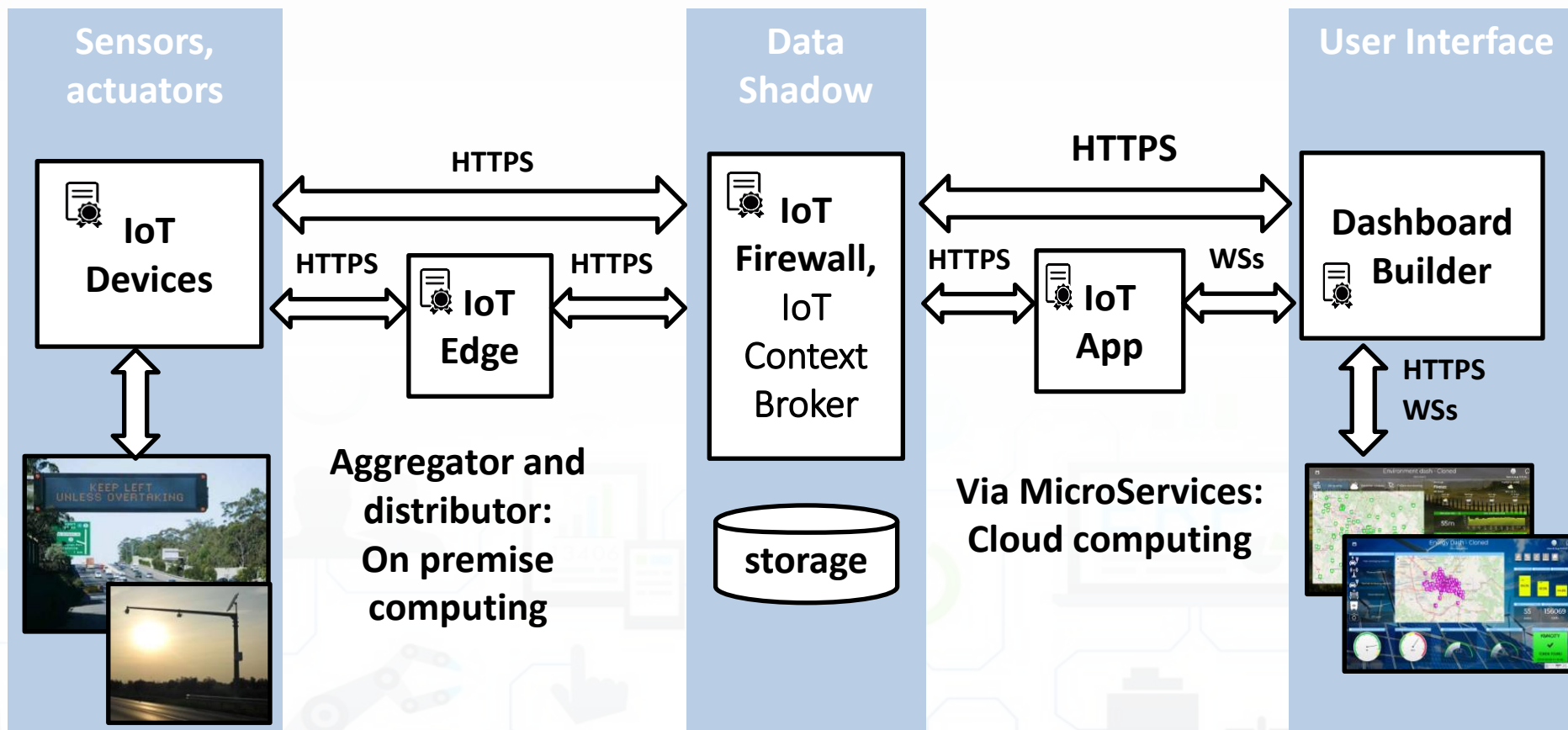
End to End security

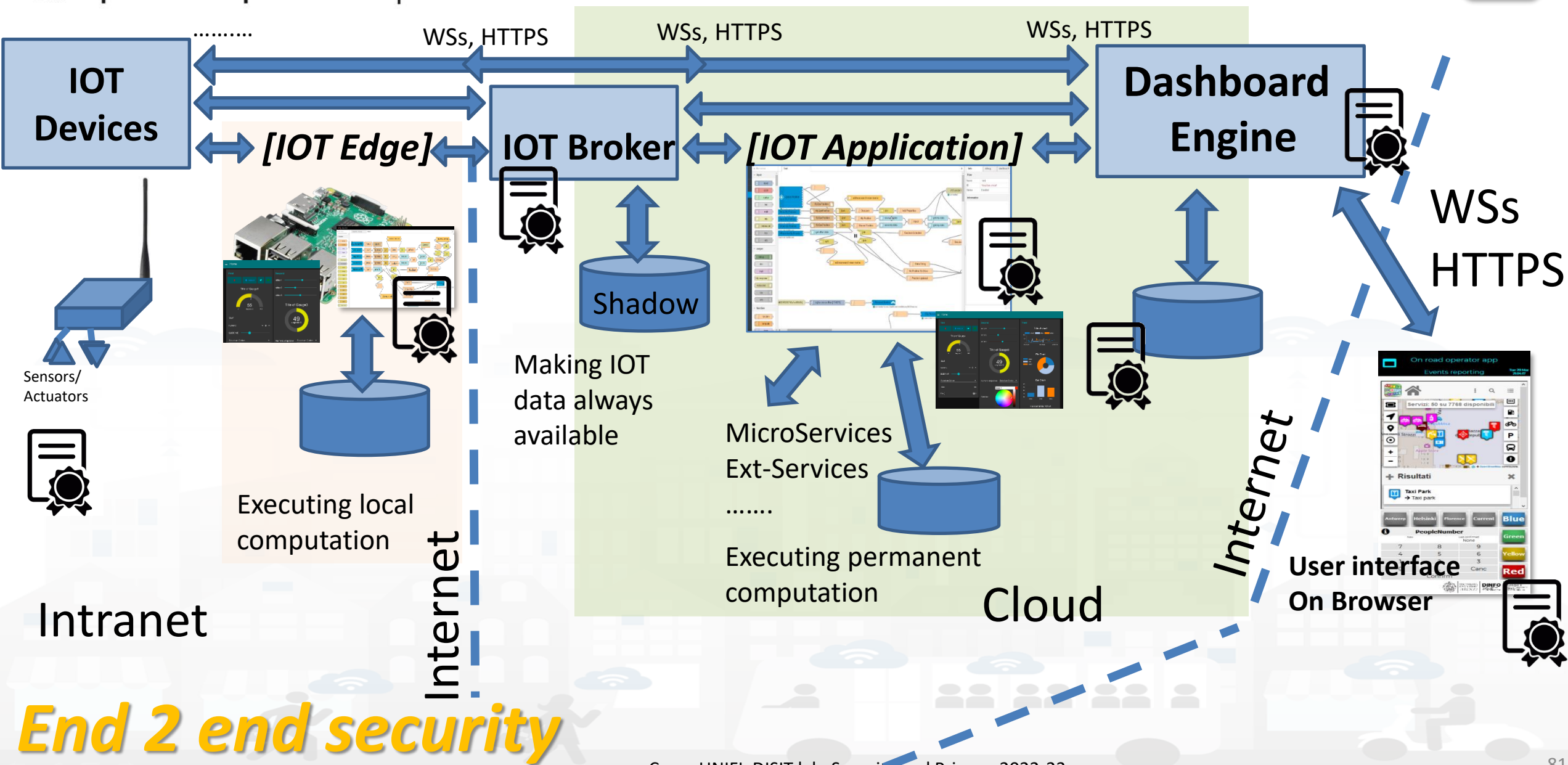
– From IOT Devices to Dashboard (user interface)

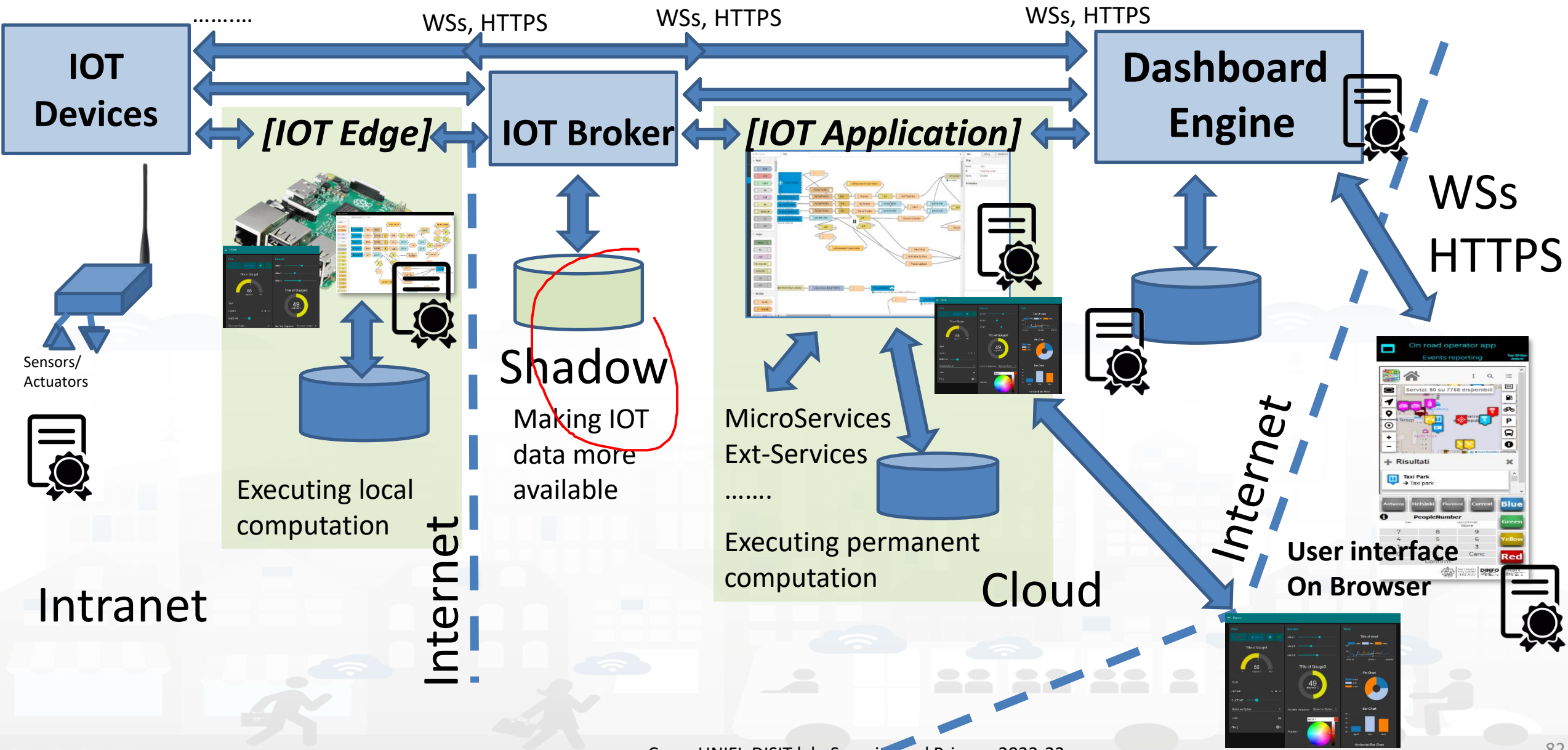
- H2M
- M2M

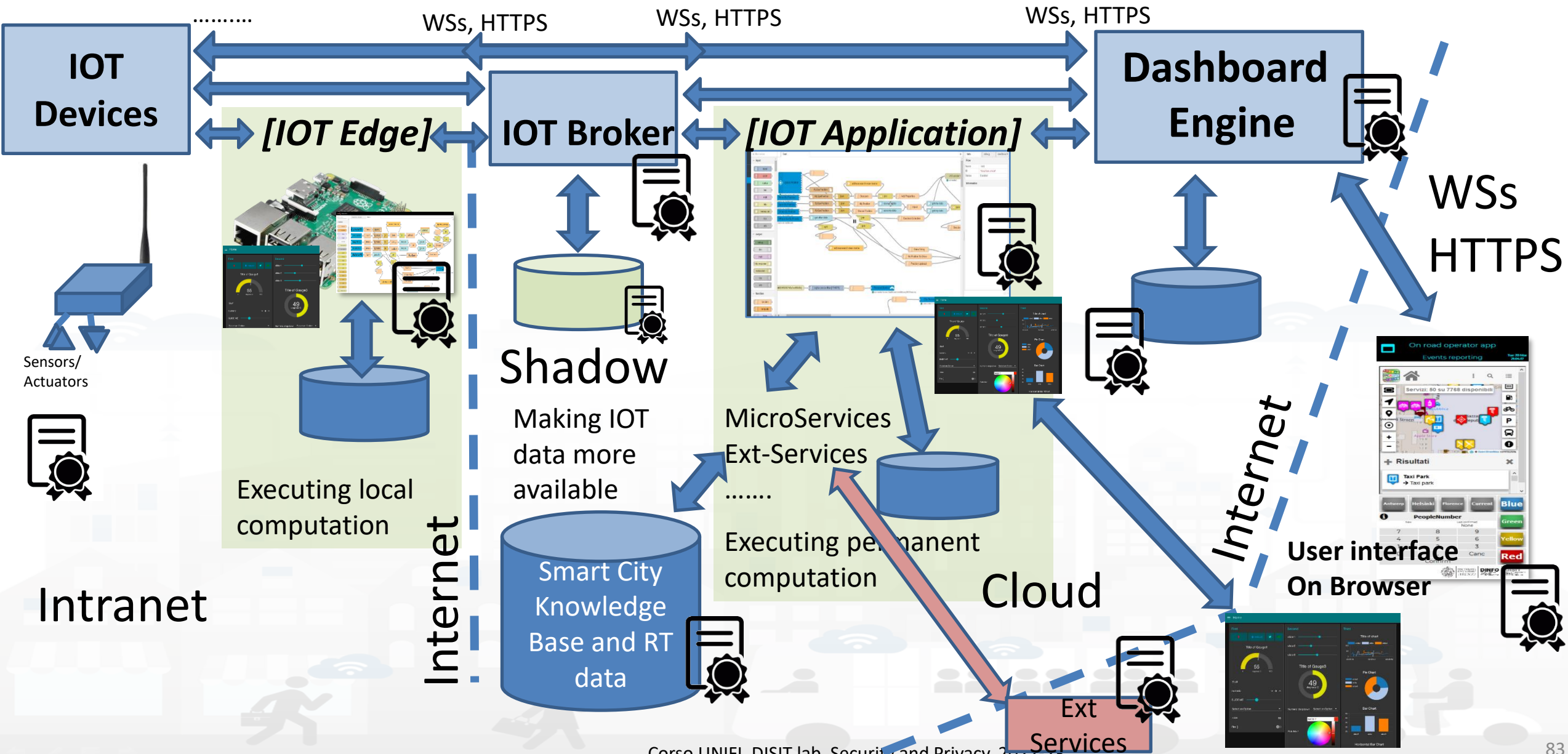


The secure stack

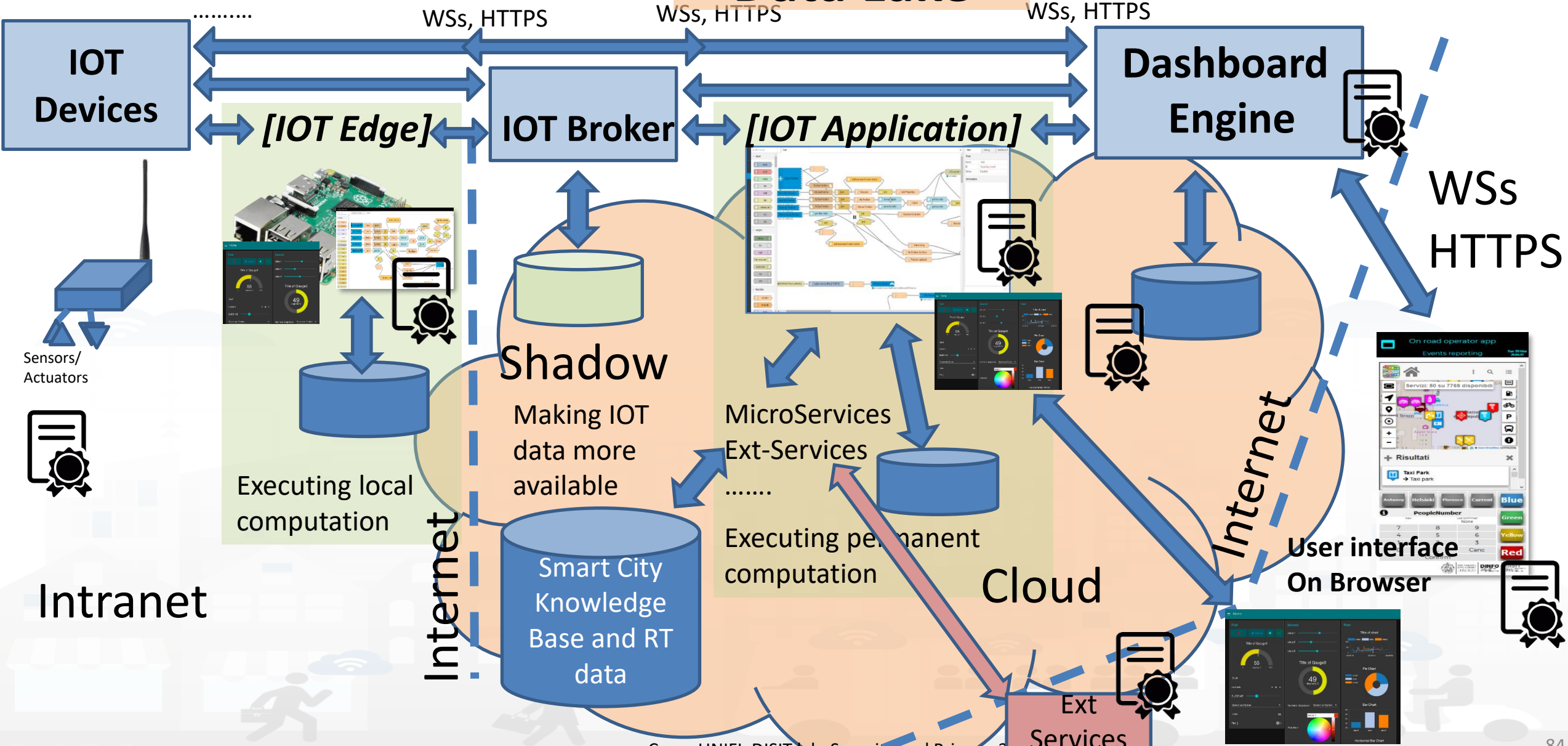




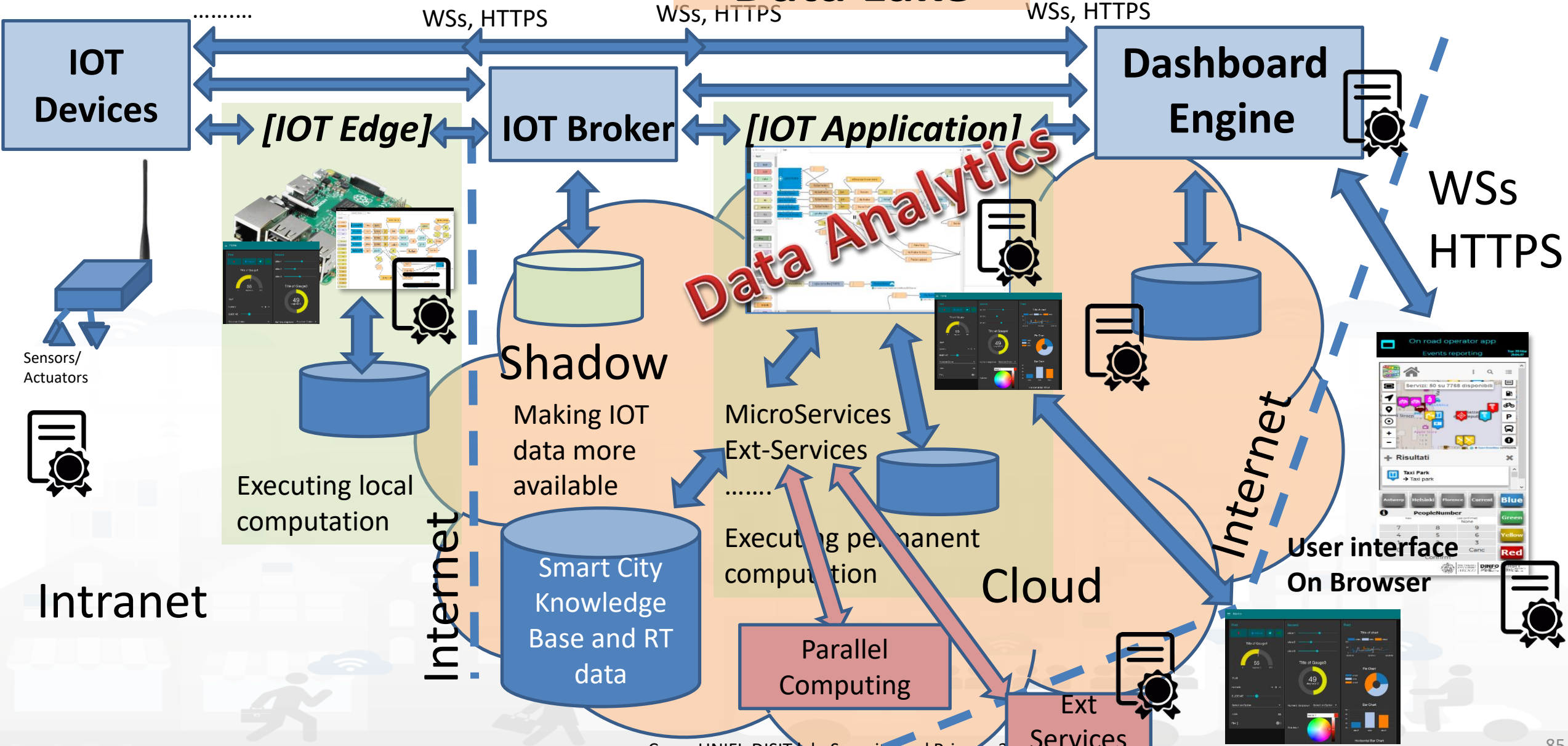


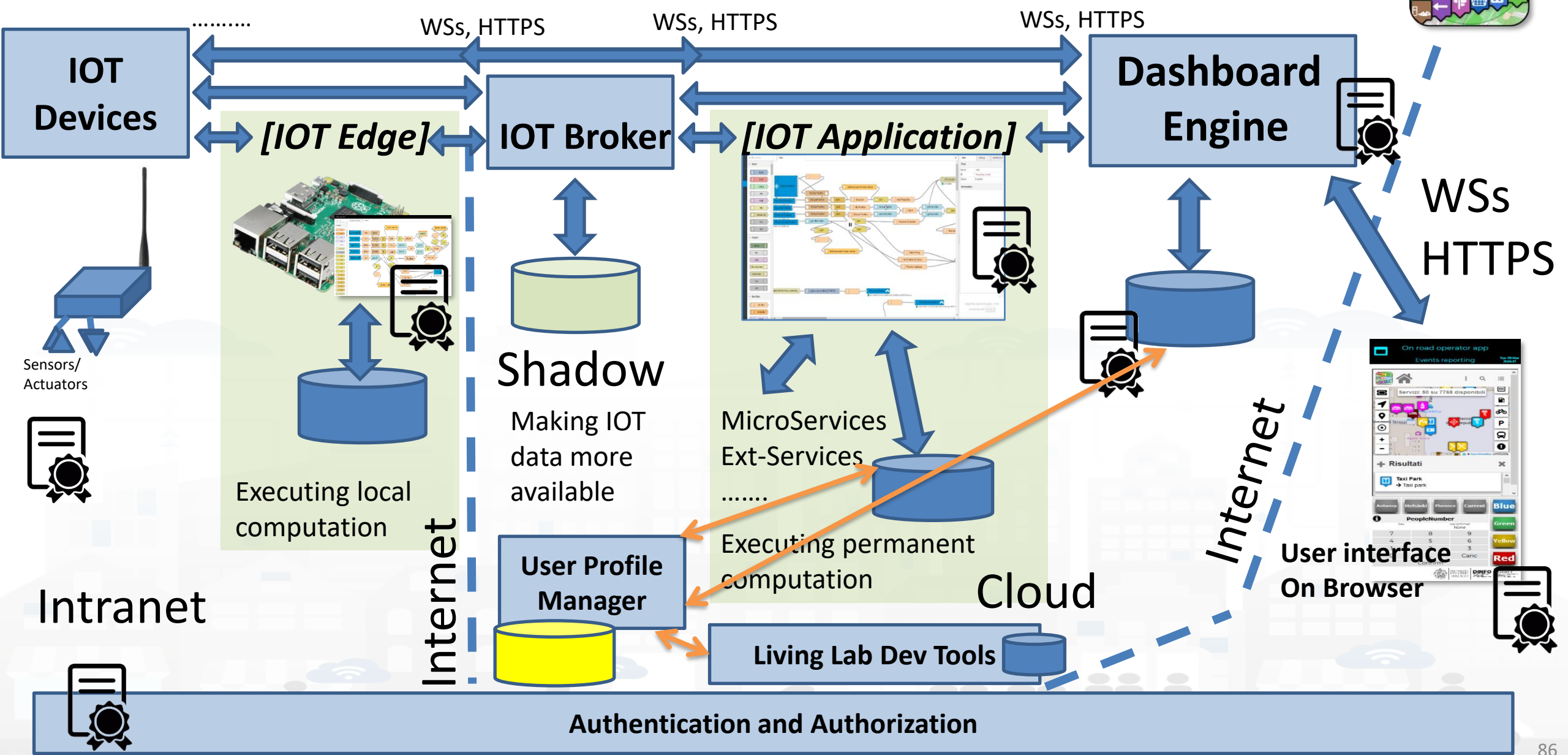


Grouping on Data Lake

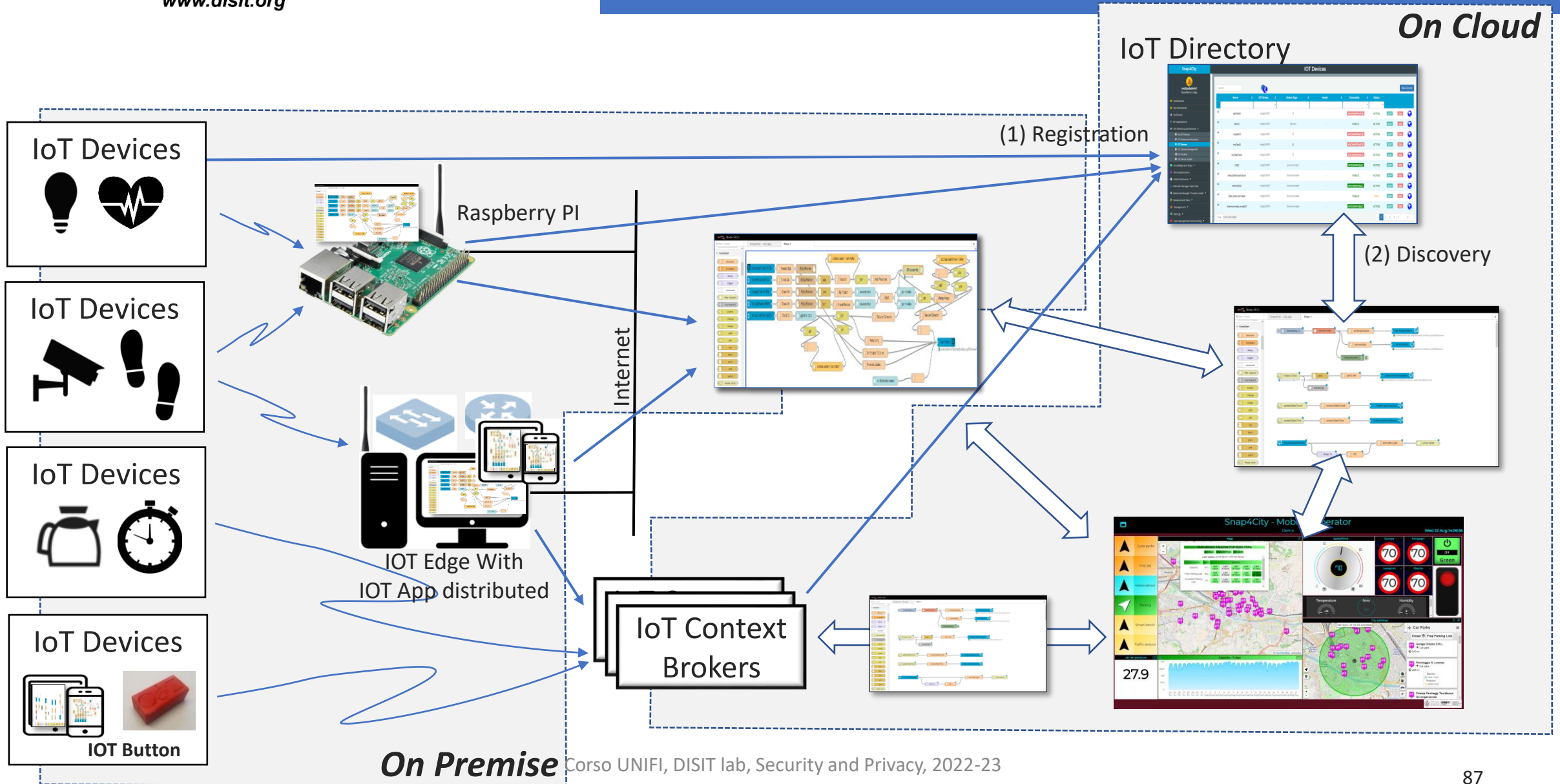


Grouping on Data Lake

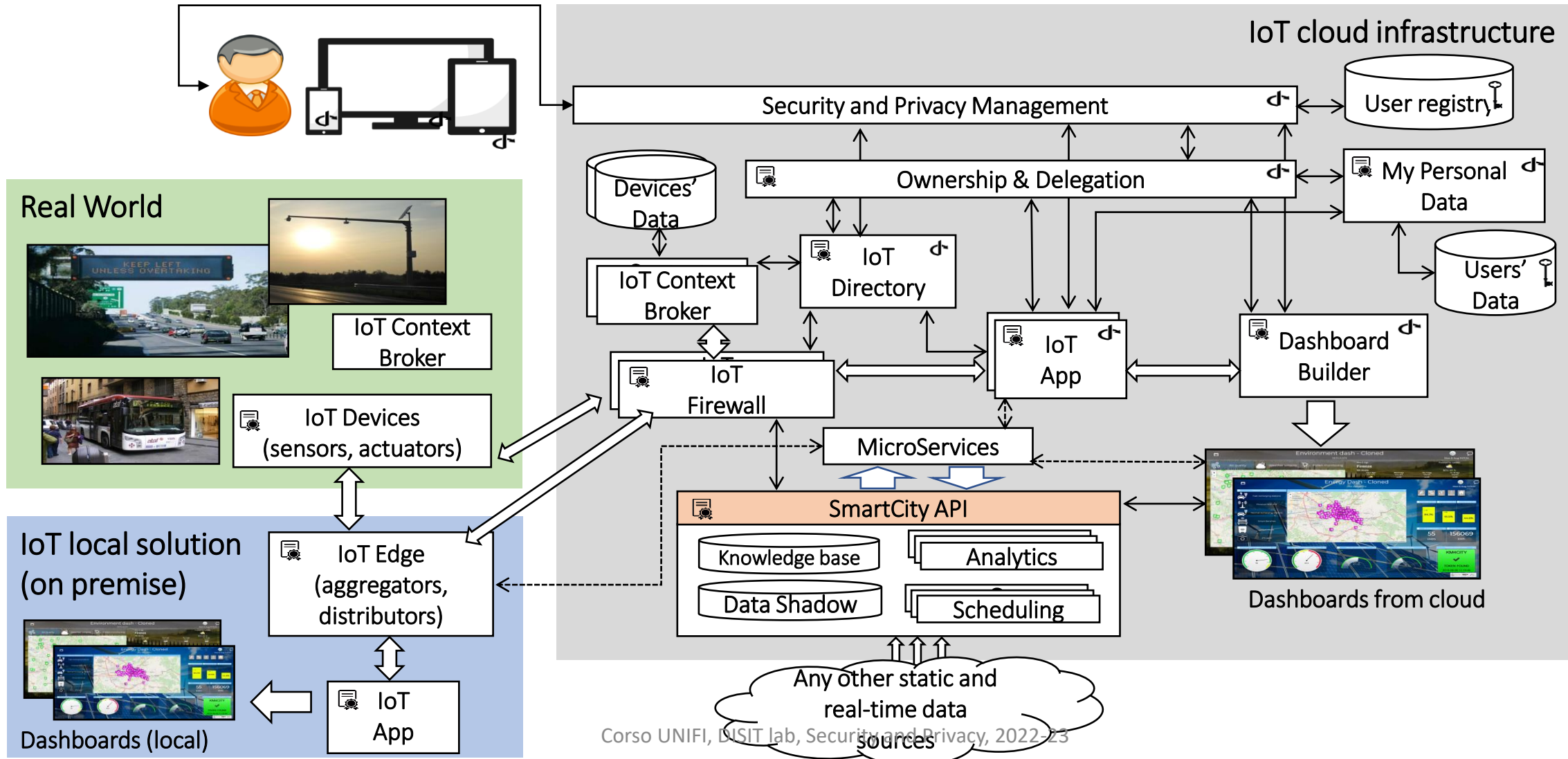




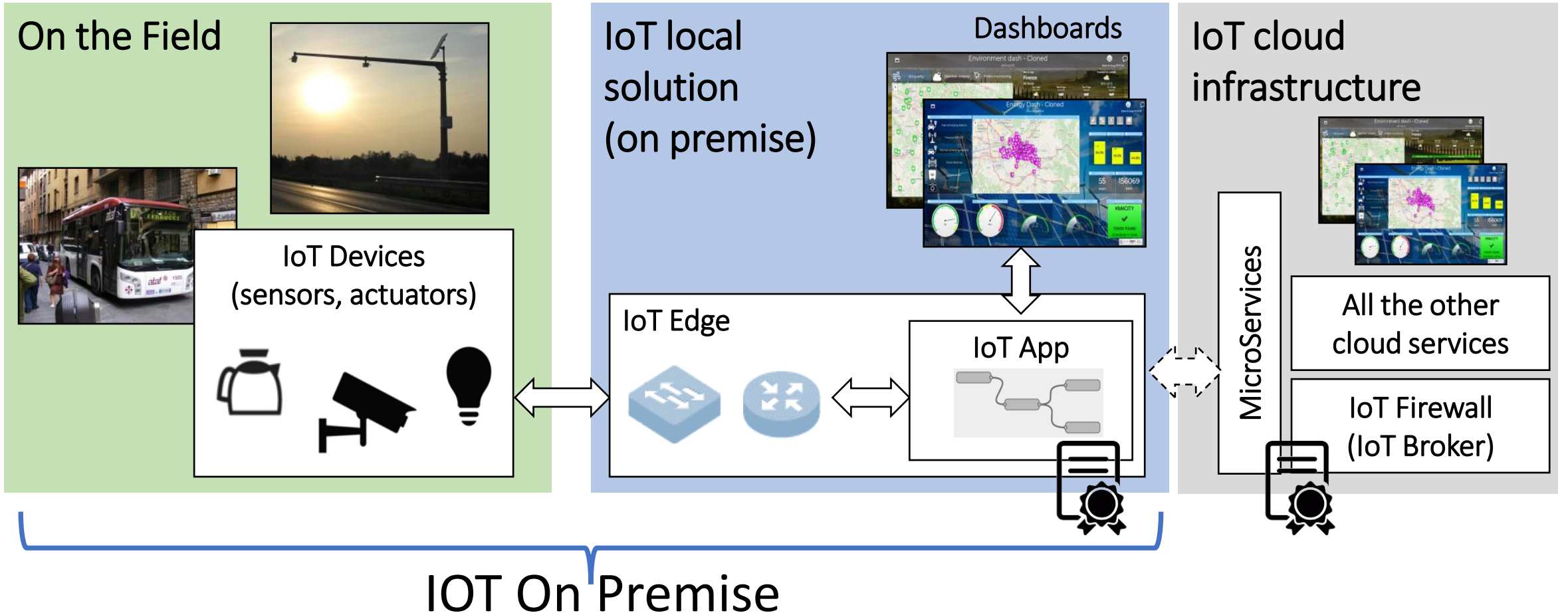
IoT/loE on the fields



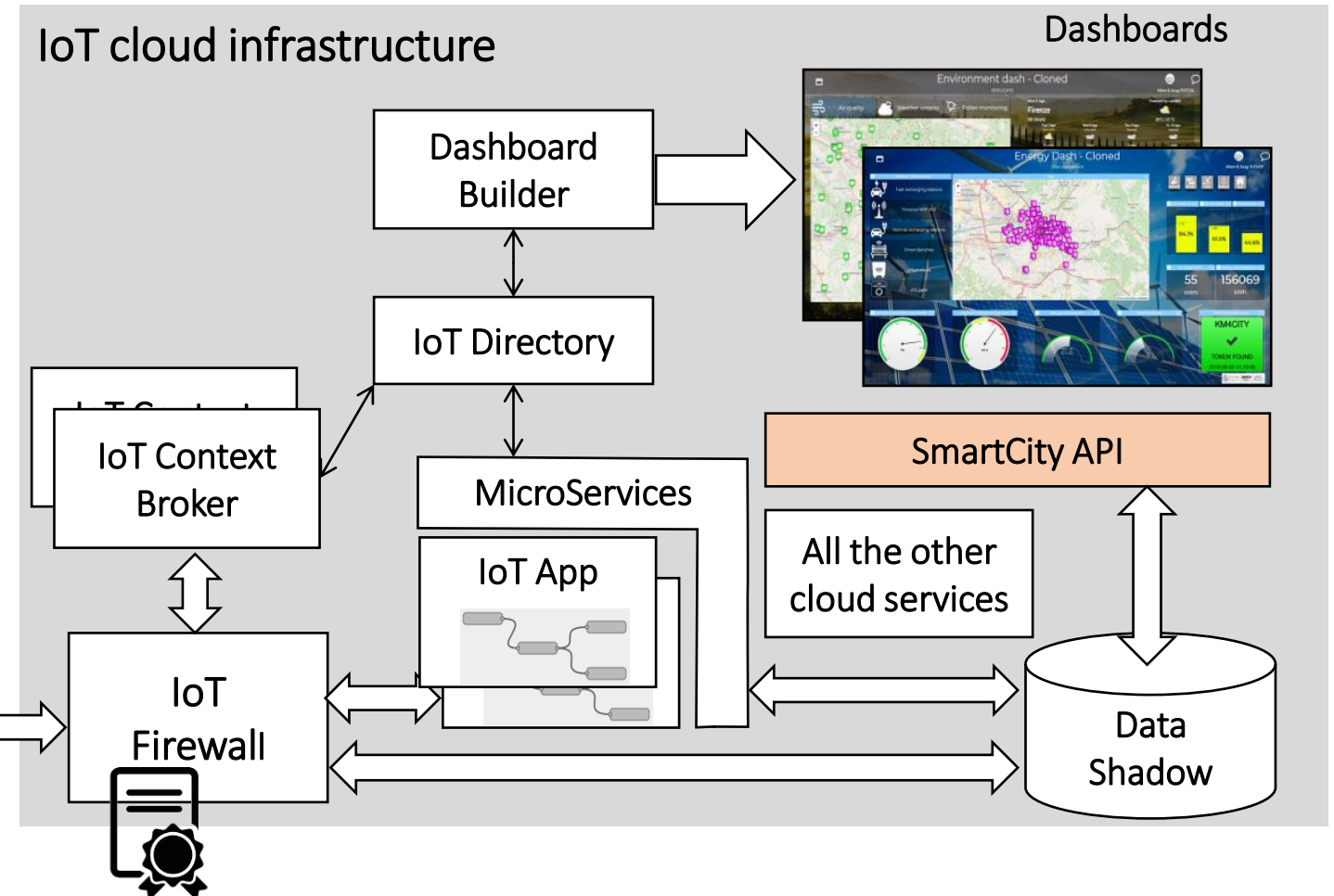
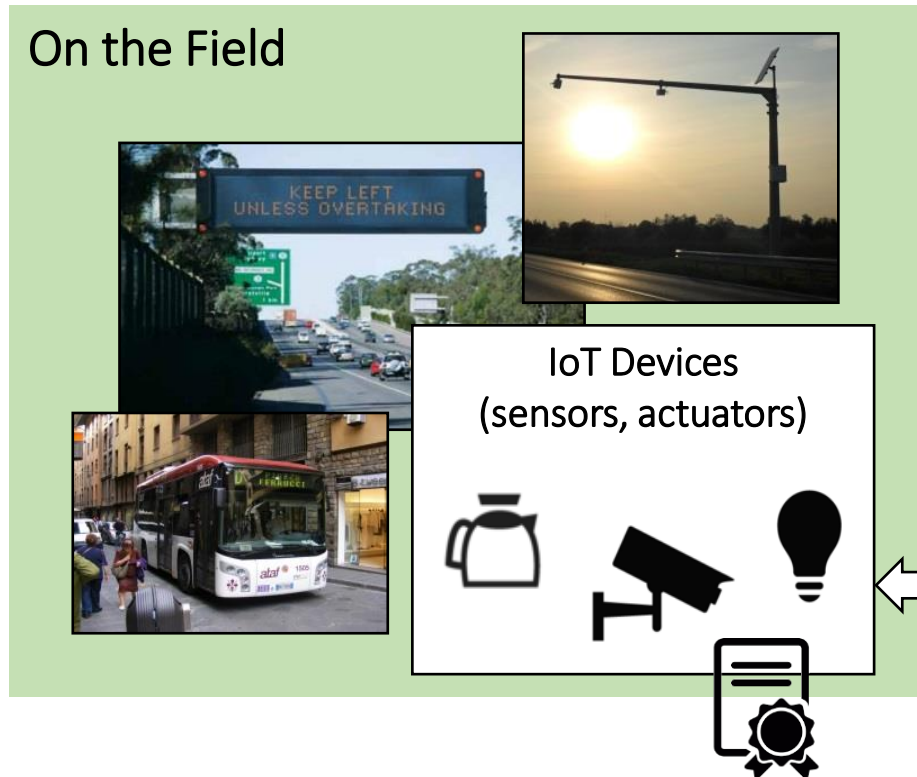
Generic IoT architecture



IOT on premise vs on cloud



IOT Devices vs on Cloud Platform



Security IoT Requirements

- **Supporting security among**

- IoT Brokers, IoT Discovery, IoT Applications, Dashboards, Storage, etc...
- Authenticated Connections: H2M, M2M
- Secure Communications: H2M, M2M
- Authorization according to the role, group, organization of the user

- **Deliver Open Software on well known platforms, end-2-end secure IoT stack**

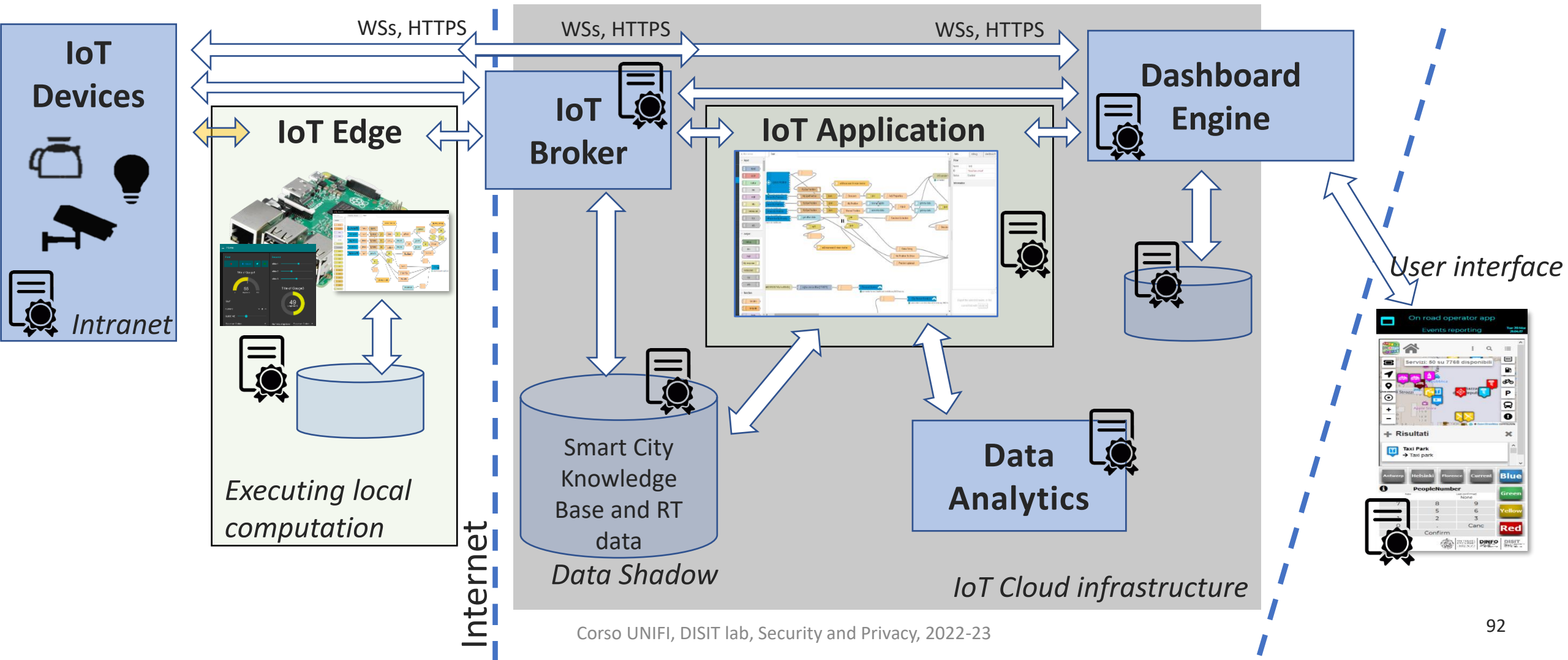
- Arduino, ESP32, Raspberry Pi, Linux, Windows, Android, etc.

- **GDPR recommendation:**

- Individuals must provide explicit consent to data collections
- Right to be forgotten
- Provide easy access to individuals data
- Explanation about how automated decision are computed against personal data
- Disclosure within 72 hours of data breach
- Data protection by design



End-to-end security



Authentication, Authorization

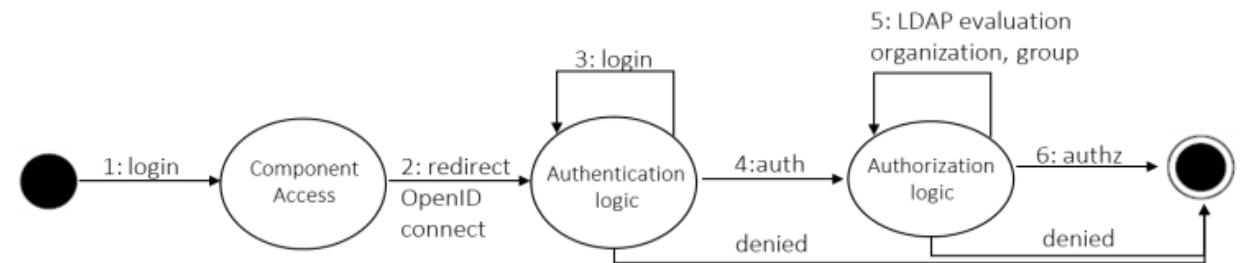
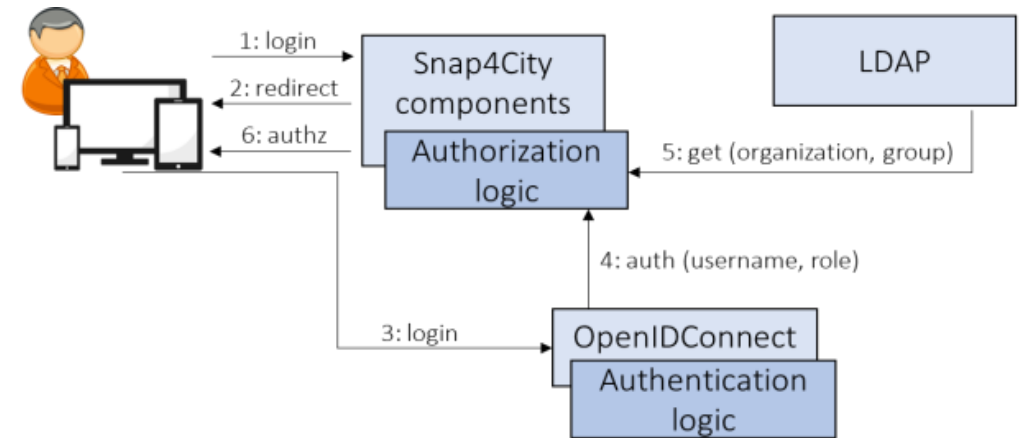
- **Authentication is performed via OpenIDConnect as (SSo) which is based on OAuth2**

- User Registry on LDAP/CRM for user data
- Authenticated users have Role of the LDAP registry
- Thus Communication start with SSL/TLS protocol, sharing a secret via JWT Token

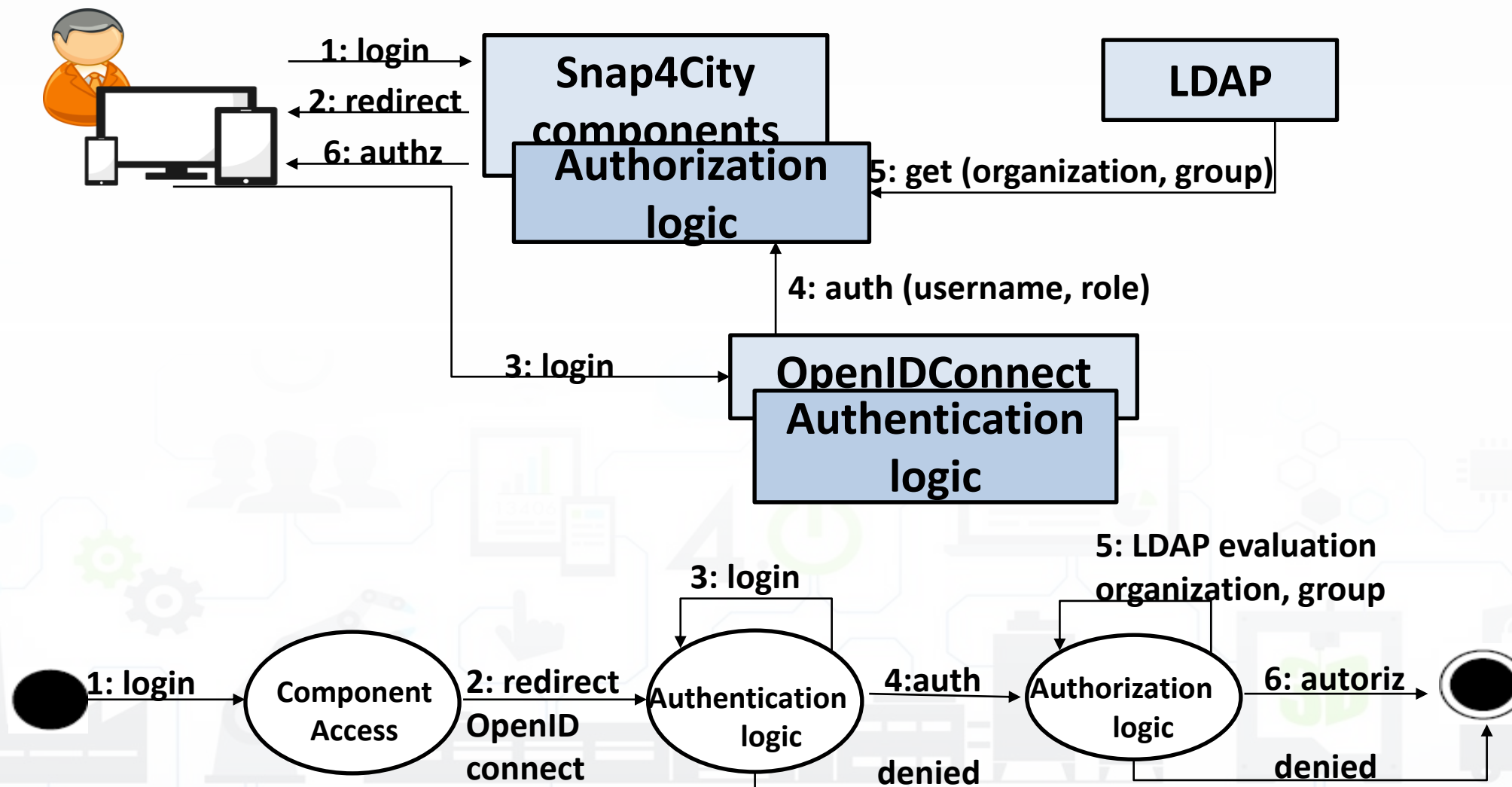
- **H2M: login is needed**

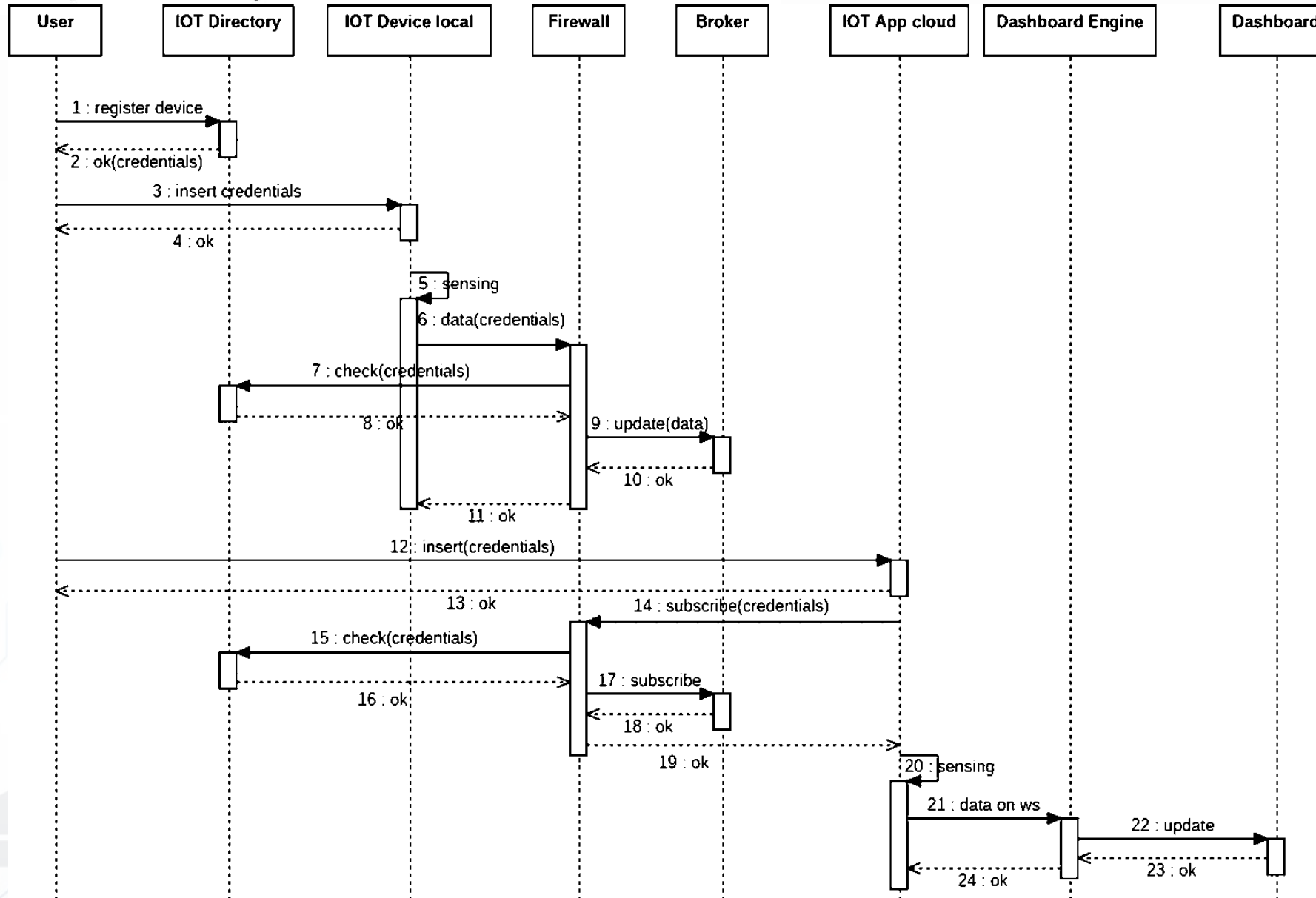
- **M2M: first time it has to be H2M**

- then a Refresh Token is retrieved based on the first JWT



Authentication & Authorization







- **From proprietary server:**

- The device are registered and data collected by the proprietary servers: SigFOX, TheThingsNetwork, etc.
- SigFOX: the server provides K1, K2 to read the data or subscribe
- TTN: other kind of keys are used for the same purpose

- **From Open Solutions**

- K1, K2 can be produced for IoT Device registration, subscription, etc.
- K1, K2, plus SHA1/3 of Certificate to establish TLS connection
- Certificate and credentials for the mutual authentications (for TLS connection)

- **Ownership and delegation**

- Identification of user data type

- **User's group, organization. User's roles**

- User's grants and rights to access data

- **Auditing, right to be forgotten**

- Values, Devices, Brokers, IoT App, Dashboards, User Profiles, time series, etc.
- Data breach intrusion detection

- **Assessment**

- User and device limit constrains



On regards GDPR (1)

- Assessment and auditing
- CMS for personal data information, encryption
- Explicit Consent, Ownership and delegation
- Roles and organization (groups) to permits fine access control
- Any collected data labelled with
 - Data of collection
 - Data of injection
 - Data of elapsing
 - Data of deleting
- +process to purge elapsed data

On regards GDPR (2)

Id	Date and Time		Username	Variable name	Motivation	Access Type	Query	Error Message	ip_address
	From...	To...							
1789	2018-05-21 13:00:34					WRITE		The passed DATA has	
1788	2018-05-21 13:00:33		prova			READ		The passed DATA has	
1787	2018-05-21 13:00:33		adifino			READ	last=10&first=4	The passed request in	
1786	2018-05-21 13:00:33								
1785	2018-05-21 13:00:32		adifino						
1784	2018-05-21 12:59:04								
1783	2018-05-21 12:59:03								
1782	2018-05-21 12:59:03								
1781	2018-05-21 12:59:02		prova						

Time	Event Type	Details								
7/19/18 5:22:05 PM	LOGIN	<table border="1"> <tr><td>Client</td><td>orionbrokerfilter</td></tr> <tr><td>User</td><td>f0ec0db7-60c8-4fb5-8820-bea6fd6602da</td></tr> <tr><td>IP Address</td><td>192.168.1.82</td></tr> <tr><td>Details</td><td>+</td></tr> </table>	Client	orionbrokerfilter	User	f0ec0db7-60c8-4fb5-8820-bea6fd6602da	IP Address	192.168.1.82	Details	+
Client	orionbrokerfilter									
User	f0ec0db7-60c8-4fb5-8820-bea6fd6602da									
IP Address	192.168.1.82									
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7/19/18 5:21:36 PM	LOGIN	<table border="1"> <tr><td>Client</td><td>orionbrokerfilter</td></tr> <tr><td>User</td><td>f0ec0db7-60c8-4fb5-8820-bea6fd6602da</td></tr> <tr><td>IP Address</td><td>192.168.1.82</td></tr> <tr><td>Details</td><td>+</td></tr> </table>	Client	orionbrokerfilter	User	f0ec0db7-60c8-4fb5-8820-bea6fd6602da	IP Address	192.168.1.82	Details	+
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IP Address	192.168.1.82									
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7/19/18 5:20:54 PM	CODE_TO_TOKEN	<table border="1"> <tr><td>Client</td><td>drupal</td></tr> <tr><td>User</td><td>becfdf0a-dee4-4d9b-9510-638712d7f919</td></tr> <tr><td>IP Address</td><td>192.168.1.82</td></tr> <tr><td>Details</td><td>+</td></tr> </table>	Client	drupal	User	becfdf0a-dee4-4d9b-9510-638712d7f919	IP Address	192.168.1.82	Details	+
Client	drupal									
User	becfdf0a-dee4-4d9b-9510-638712d7f919									
IP Address	192.168.1.82									
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7/19/18 5:20:53 PM	LOGIN	<table border="1"> <tr><td>Client</td><td>drupal</td></tr> <tr><td>User</td><td>becfdf0a-dee4-4d9b-9510-638712d7f919</td></tr> <tr><td>IP Address</td><td>192.168.1.82</td></tr> <tr><td>Details</td><td>+</td></tr> </table>	Client	drupal	User	becfdf0a-dee4-4d9b-9510-638712d7f919	IP Address	192.168.1.82	Details	+
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IP Address	192.168.1.82									
Details	+									
7/19/18 5:20:53 PM	CODE_TO_TOKEN	<table border="1"> <tr><td>Client</td><td>php-dashboard-builder</td></tr> <tr><td>User</td><td>becfdf0a-dee4-4d9b-9510-638712d7f919</td></tr> <tr><td>IP Address</td><td>192.168.1.82</td></tr> <tr><td>Details</td><td>+</td></tr> </table>	Client	php-dashboard-builder	User	becfdf0a-dee4-4d9b-9510-638712d7f919	IP Address	192.168.1.82	Details	+
Client	php-dashboard-builder									
User	becfdf0a-dee4-4d9b-9510-638712d7f919									
IP Address	192.168.1.82									
Details	+									

Simple view: displaying all attributes...

cn ● AreaManager

objectClass ● organizationalRole ● top

roleOccupant ● cn=gpantaleo,dc=ldap,dc=disit,dc=org ● cn=mmarazzini0,dc=ldap,dc=disit,dc=org ● cn=fbambagioni,dc=ldap,dc=disit,dc=org ● cn=snapp4city,dc=ldap,dc=disit,dc=org ● cn=dbologna2,dc=ldap,dc=disit,dc=org ● cn=developer1,dc=ldap,dc=disit,dc=org ● cn=dashboard,dc=ldap,dc=disit,dc=org ● cn=elefellous,dc=ldap,dc=disit,dc=org ● cn=micheladisit,dc=ldap,dc=disit,dc=org ● cn=areamenager3,dc=ldap,dc=disit,dc=org ● cn=areamenager4,dc=ldap,dc=disit,dc=org ● cn=a.ksiba,dc=ldap,dc=disit,dc=org ● cn=kaisa.sibelius@forumvirium.fi,dc=ldap,dc=disit,dc=org ● cn=a.crisci,dc=ldap,dc=disit,dc=org ● cn=tester20,dc=ldap,dc=disit,dc=org ● cn=Belliniema,dc=ldap,dc=disit,dc=org ● cn=lorenzotomassoli,dc=ldap,dc=disit,dc=org ● cn=samuelemeta,dc=ldap,dc=disit,dc=org ● cn=ipsaro.palesi,dc=ldap,dc=disit,dc=org ● cn=Pierfrancesco Bellini,dc=ldap,dc=disit,dc=org ● cn=Giorgio Schembri,dc=ldap,dc=disit,dc=org ● cn=GBaraldo,dc=ldap,dc=disit,dc=org ● cn=p.zamperlin,dc=ldap,dc=disit,dc=org ● cn=pamela,dc=ldap,dc=disit,dc=org ● cn=manuelpezzera,dc=ldap,dc=disit,dc=org ● cn=gp.antw.test,dc=ldap,dc=disit,dc=org ● cn=gp.helsinki.test,dc=ldap,dc=disit,dc=org ● cn=stefanobilotta,dc=ldap,dc=disit,dc=org

- Unified Login → via Keycloak + LDAP
- My Personal Data
- Data auditing
- Federated modules
- IoT Directory and certificates
- IoT Button
- IoT Dashboard

- C. Badii, P. Bellini, A. Difino, P. Nesi, "Smart City IoT Platform Respecting GDPR Privacy and Security Aspects", accepted for publication on IEEE Access, 2020. 10.1109/ACCESS.2020.2968741 <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8966344>

Smart City IoT Platform Respecting GDPR Privacy and Security Aspects

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ABSTRACT The Internet of Things (IoT) paradigm enables computation and communication among tools that everyone uses daily. The vastness and heterogeneity of devices and their composition offer innovative services and scenarios that require a new challenging vision in interoperability, security and data management. Many IoT frameworks and platforms claimed to have solved these issues, aggregating different sources of information, combining their data flows in new innovative services, providing security robustness with respect to vulnerability and respecting the GDPR (General Data Protection Regulation) of the European Commission. Due to the potentially very sensible nature of some of these data, privacy and security aspects have to be taken into account by design and by default. In addition, an end-to-end secure solution has to guarantee a secure environment at the final users for their personal data, in transit and storage, which have to remain under their full control. In this paper, the Snap4City architecture and its security solutions that also respect the GDPR are presented. The Snap4City solution addresses the full stack security, ranging from IoT Devices, IoT Edge on premises, IoT Applications on the cloud and on premises, Data Analytics, and Dashboarding, presenting a number of integrated security solutions that go beyond the state of the art, as shown in the platform comparison. The stress test also included the adoption of penetrations tests verifying the robustness of the solution with respect to a large number of potential vulnerability aspects. The stress security assessments have been performed in a piloting period with more than 1200 registered users, thousands of processes per day, and more than 1.8 million of complex data ingested per day, in large cities such as Antwerp, Helsinki and the entire Tuscany region. Snap4City is a solution produced in response to a research challenge launched by the Select4Cities H2020 research and development project of the European Commission. Select4Cities identified a large number of requirements for modern Smart Cities that support IoT/IoE (Internet of Things/Everything) in the hands of public administrations and Living Labs, and selected a number of solutions. Consequently, at the end of the process after 3 years of work, Snap4City has been identified as the winning solution.

INDEX TERMS End-2-end, GDPR, IoT, security, smart city.

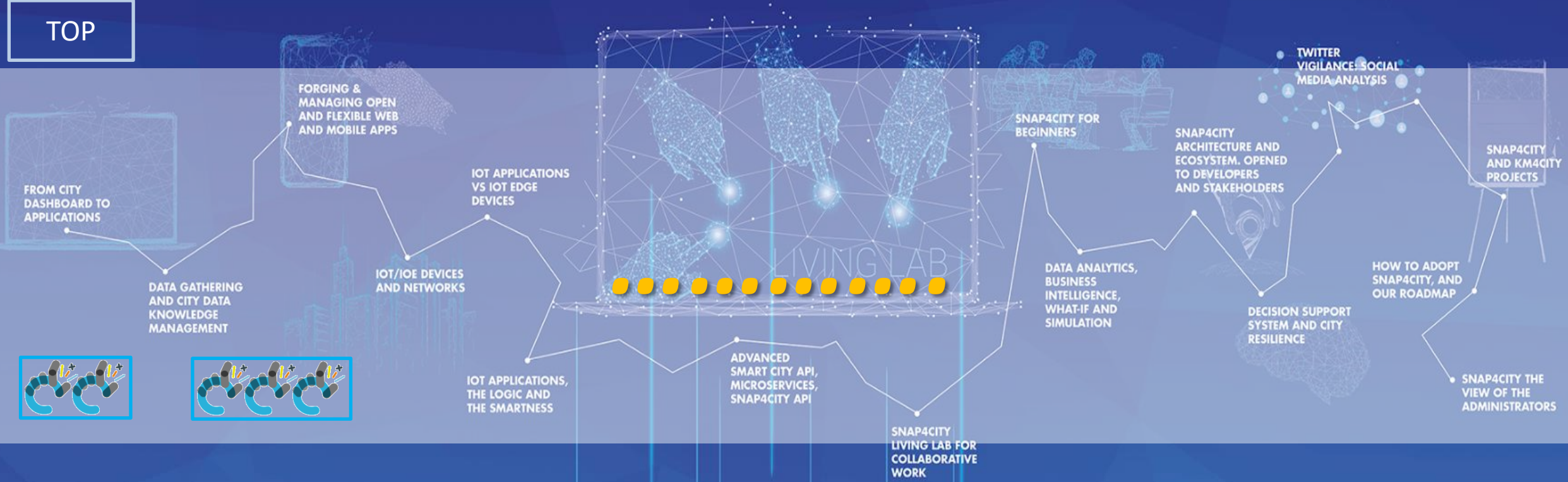
I. INTRODUCTION

IoT (Internet of Thing) is becoming a disruptive technology, especially for city users of metropolitan areas. The pervasiveness of IoT Devices, integrated in common objects, is becoming increasingly deeper. The addresses' space for these devices would be enough to point any sensors of any devices at any moment without restrictions. Diffuse products that implement *Low-Power Wide Area Networks* (LPWAN)

technologies for IoT introduced by SigFox and Semtech (LoRa, Long Range) have been gaining interest and have been under intense deployment campaigns worldwide [1]. At the same time, *short range* IoT devices (based on technologies such as IEEE 802.15.4 or Bluetooth Low Energy, BLE, [2]) are sold in increasing quantities and are already able to support scenarios for smart homes, energy metering and industrial automation. On the other hand, the start of the diffusion of *5G devices* and services is creating high expectations in networking IoT technologies, as the killer application of previous technologies in metropolitan areas.

The associate editor coordinating the review of this manuscript and approving it for publication was Adnan M. Abu-Mahfouz.

SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES





Any Devices in the IoT ecosystem

- Microcontroller ESP8266, Arduino
- Raspberry boards
- AirQino, Libelium
- Android devices
- PC
- On cloud virtualization
- As much as user friendly VS as much as secure channel

Security Strength	Symmetric key algorithms	FFC (e.g., DSA, D-H)	IFC (e.g., RSA)	ECC (e.g., ECDSA)
≤ 80	2TDEA ²¹	$L = 1024$ $N = 160$	$k = 1024$	$f = 160-223$
112	3TDEA	$L = 2048$ $N = 224$	$k = 2048$	$f = 224-255$
128	AES-128	$L = 3072$ $N = 256$	$k = 3072$	$f = 256-383$
192	AES-192	$L = 7680$ $N = 384$	$k = 7680$	$f = 384-511$
256	AES-256	$L = 15360$ $N = 512$	$k = 15360$	$f = 512+$

- On embedded devices, cypher suite not always available. Use: `TLS_RSA_WITH_AES_256_CBC_SHA`
- Impact of certificate size on available heap: NIST Special Publication suggestions: Use 2048, but WARNING close future!

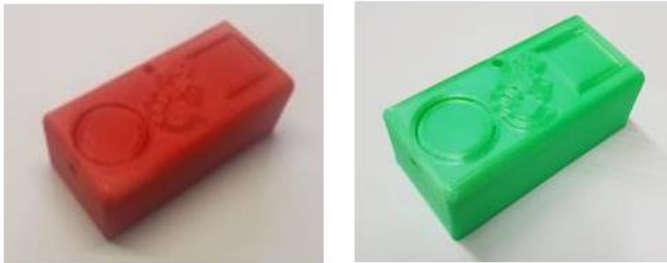
Any Devices in the IoT ecosystem (2)

<https://www.snap4city.org/drupal/node/276>

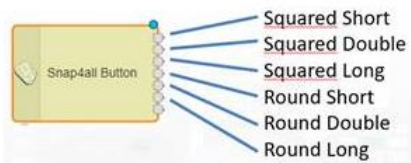
Home / Snap4All IOT Button: based on ESP32, NGSI compliant secure connection

Snap4All IOT Button: based on ESP32, NGSI compl

Snap4All IOT Button Version 3 is based on ESP32: it is an NGSI devices, which can be customize as well. It is a secure device with Mutual authentication and secure encrypted connection.

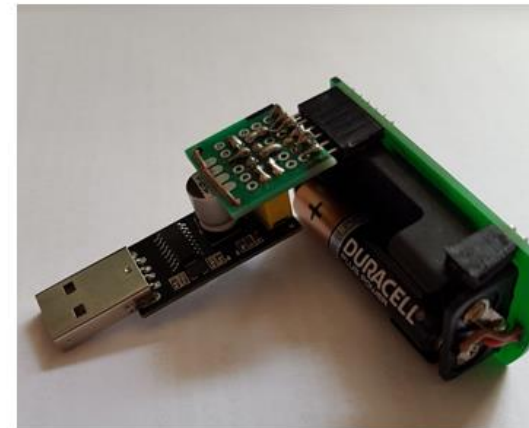


Once you have registered and configured can connect them by using MicroService Node/block in IOT Application by using:



To connect the device to a USB you will need a serial adapter for ESP01 or a USB to Serial adapter.

Pins are connected from left to right: GND, CTS, 3.3V, TX, RX, DTR.



In case you are using an ESP01 programming adapter make sure to connect pin as in photo.



The source code of version 2.0 is: <https://www.snap4city.org/download/video/IOTbuttonSmdV2-005a.rar>

Any Devices in the IoT ecosystem (3)

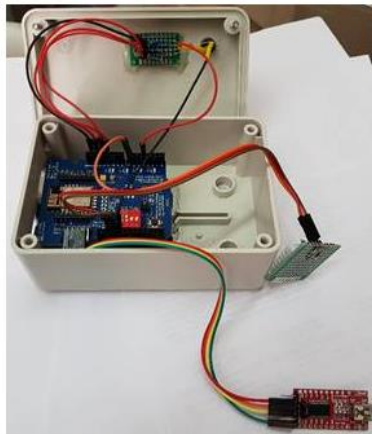
<https://www.snap4city.org/drupal/node/329>

Home / Snap4City: Arduino & ESP8266 IOT Device NGSI

Snap4City: Arduino & ESP8266 IOT Device NGSI

Arduino & ESP8266 – user Guide and developers guide:

It is a secure device with Mutual authentication and secure encrypted connection.



<https://www.snap4city.org/drupal/node/518>

Home / Solution: using PAX Counters, monitoring museum and events

Solution: using PAX Counters, monitoring museum and events

In this example, the interaction with IOT Devices counting people by using Wi-Fi and Bluetooth sniffing in its vicinity according to Figure 12, a mobile PAXCounter based on ESP32 sending messages to Snap4City via LoraWAN. see <https://www.snap4city.org> Other simpler versions can be located on fixed places, and may also use WiFi to send the obtained measures including additional 22 devices have been installed. The measured values are sent to LoraWan operator The Things Network, which does not provide



Figure 12: A mobile PAX counter based on ESP32.

Museum Case

Considering the example of the museum, one could be interested in monitoring the flow of entering and exiting visitors, having stored, for example into MyKPI, MyPOI storage via MicroServices. This approach of Snap4City allows at the IOT Developers an IOT App has been created for PaxCounter to receive in Event Driven mode the new coming from The Things Network Dashboard Wizard automatically sees the data entity on the MyKPI and allowed us to automatically create Widgets showing time and derived data. All the derived values of the initial real time data can be computed in real time, saved on personal storage as the difference between the people entering the museum and those leaving to obtain the number of people inside the museum in

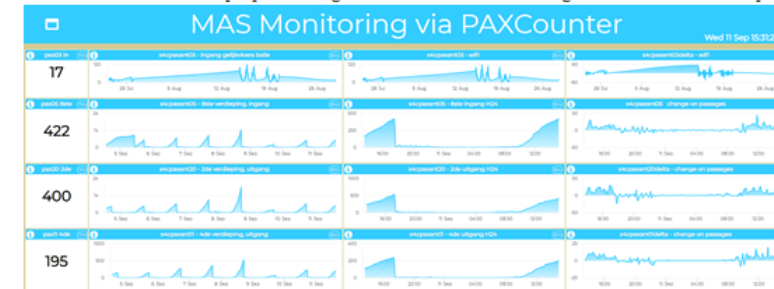


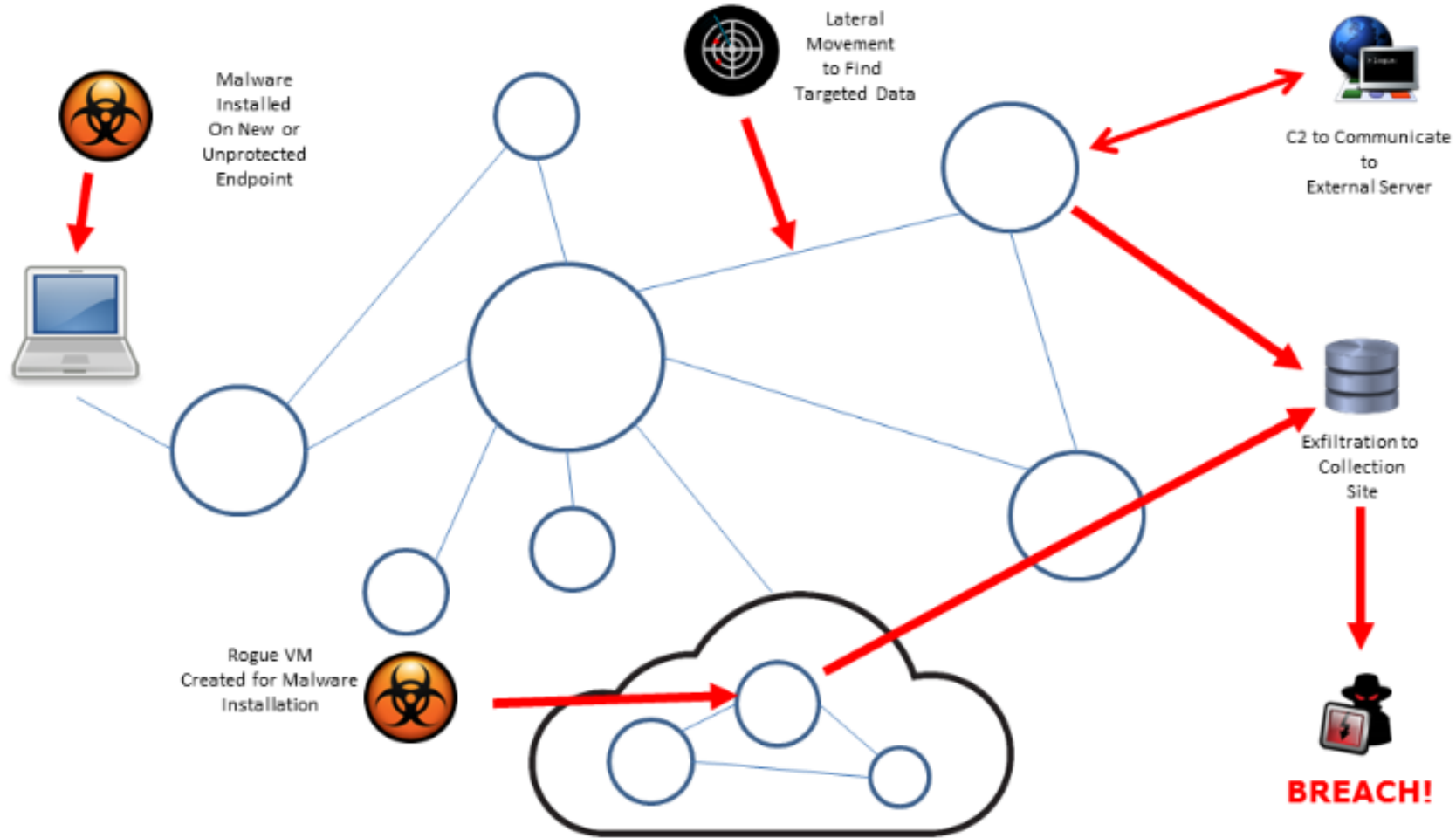
Figure 13: Monitoring MAS Museum people flows.



More on breach (1)

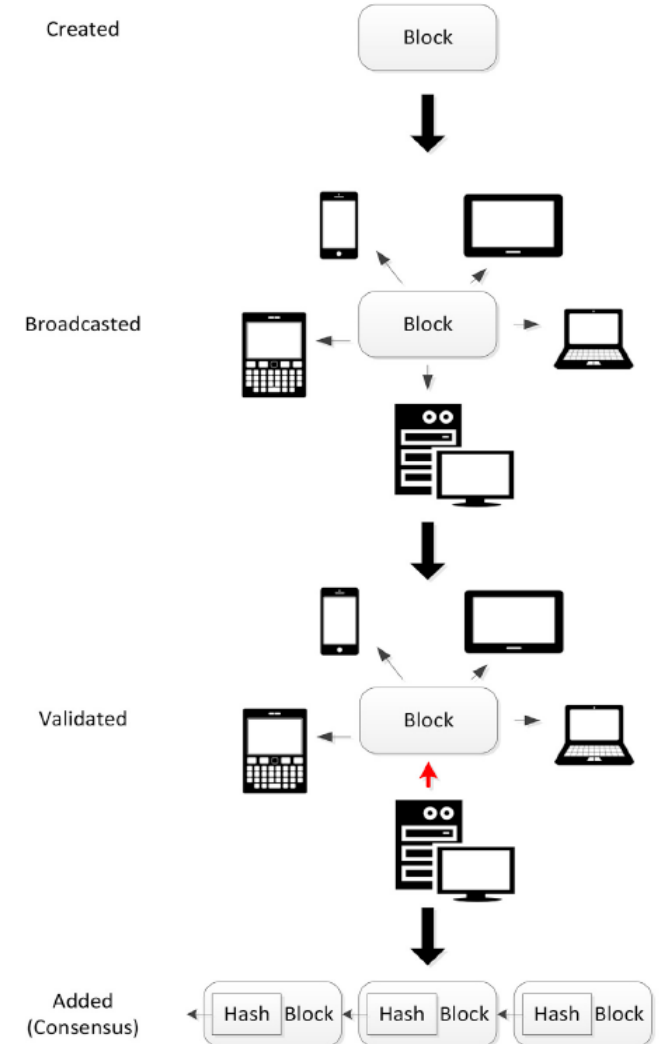
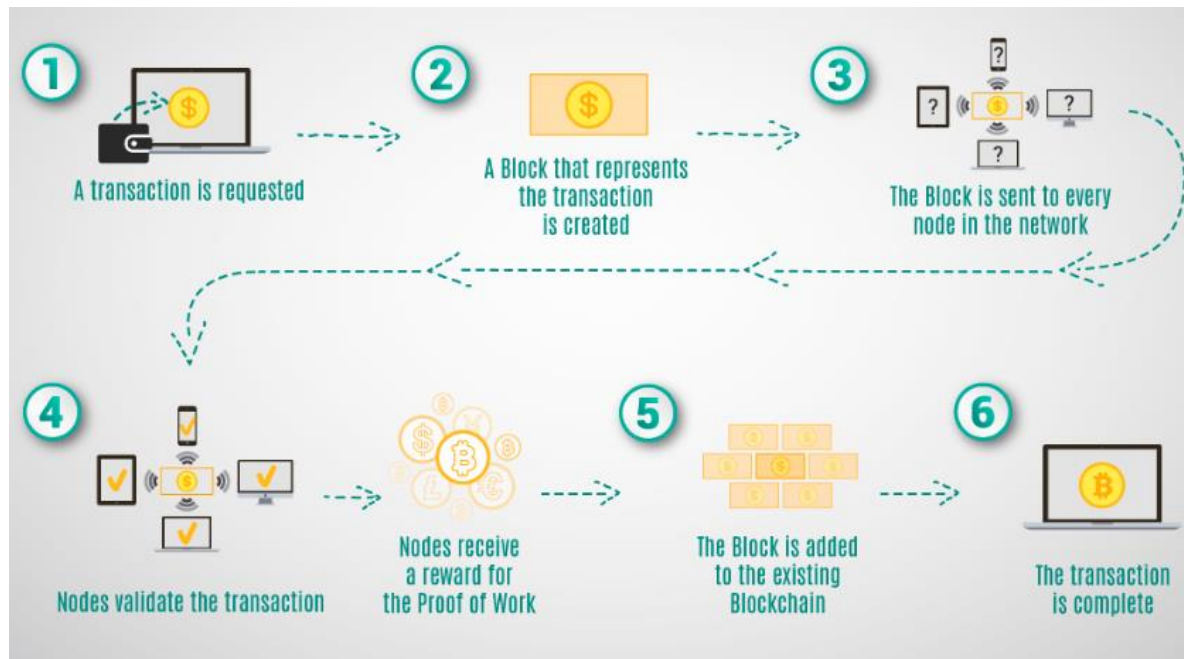
- Dangerous examples of network vulnerabilities include
 - Improperly configured routing causing leak paths in between protected network enclaves or to the Internet itself
 - Temporary or test configurations of firewalls that don't operate as designed or don't get reversed-out properly
 - Password password password
 - Password password password
 - Network analysis in real-time → dashboards, acceptable level of traffic, trigger of alarm → Notification (SMS, Mail, Calls leveraged depending on the sensitivity)
- Two authenticate factors → FIDO2 with hardware support

More on breach (2)



Blockchain solution (1)

- One node validates the block (called mining in bitcoin) and broadcasts it back to the network.
- The nodes add the block to their chain of blocks if the blocks is verified and the block correctly references the previous block



Blockchain solution (2)

- Central hub that maintains references of member repository where the datasets are actually stored and distributed
- Delete from Block chain?
- Rule enforcement (everything distributed)?
- ... work in progress

