From IoT to large architettures and programming on them

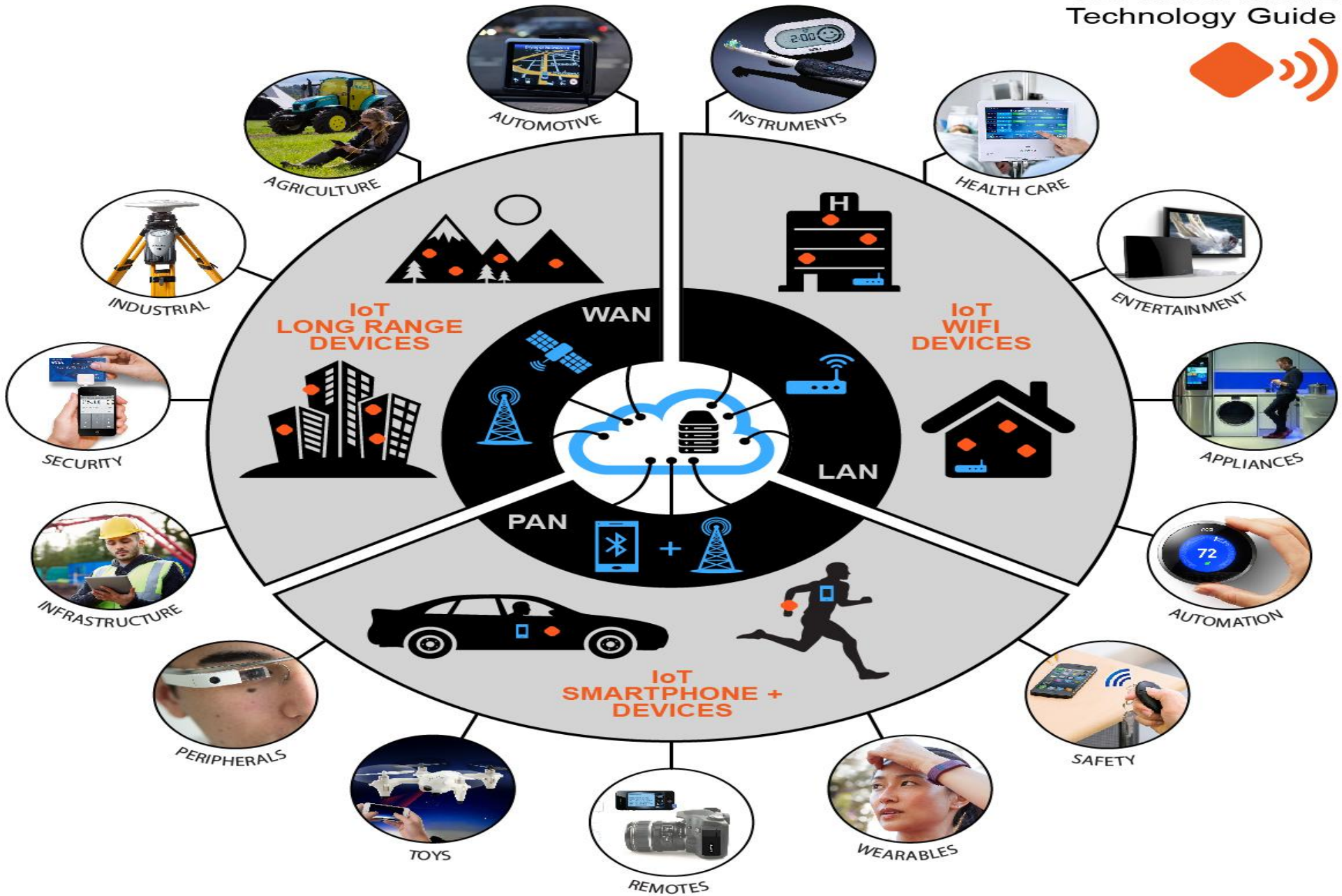


Big Data Architectures

Paolo Nesi

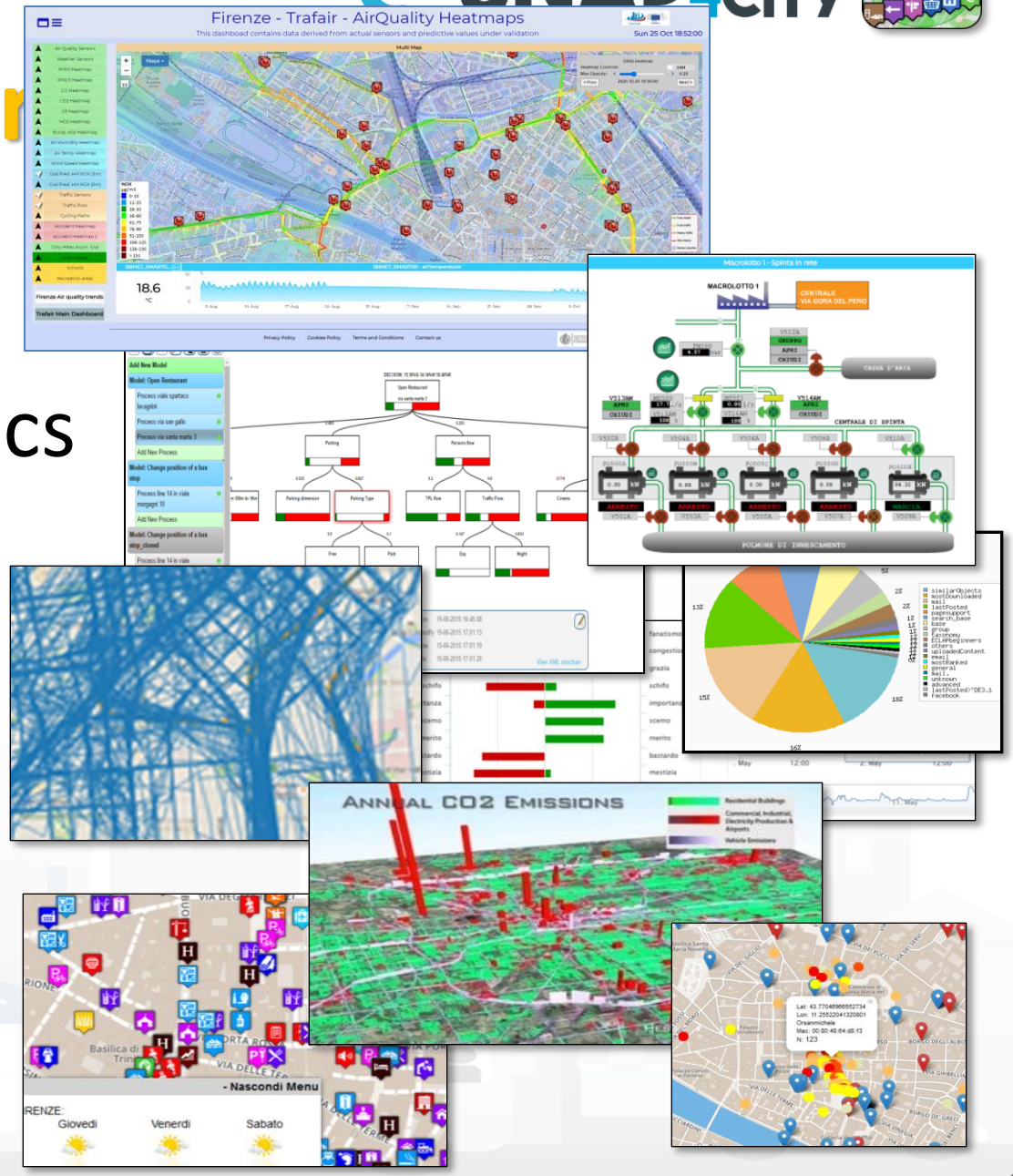
DISIT Lab, UNIFI

2026

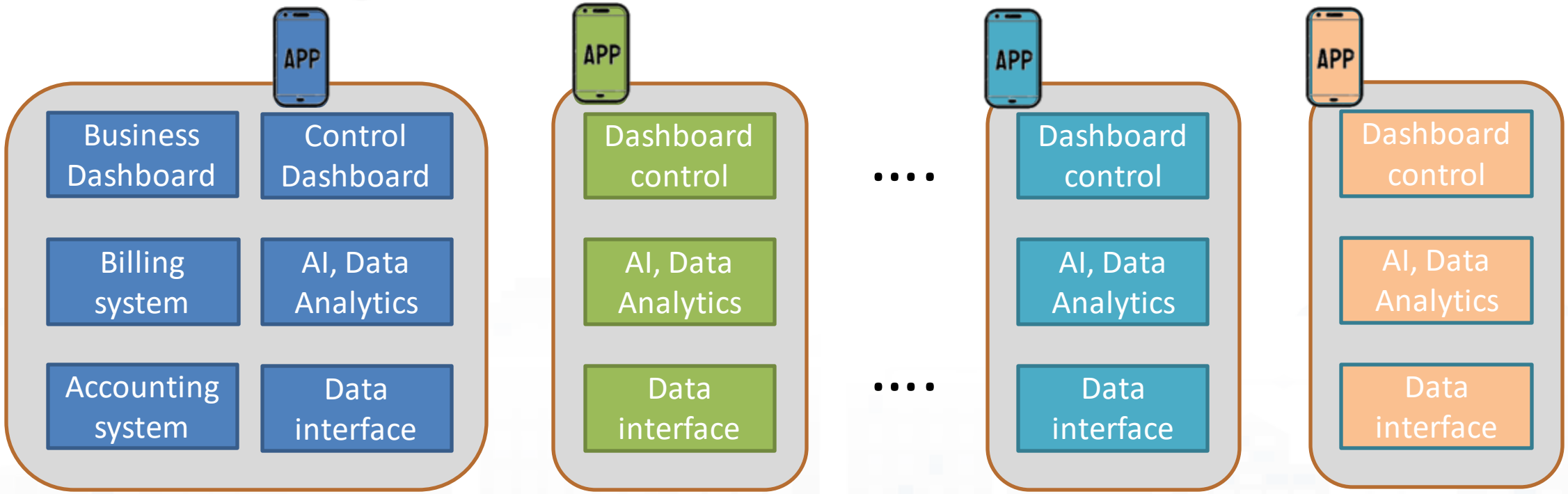

IoT HARDWARE
Technology Guide
AUTOMOTIVE
INSTRUMENTS
AGRICULTURE
HEALTH CARE
INDUSTRIAL
ENTERTAINMENT
IoT
LONG RANGE
DEVICES
WAN
IoT
WIFI
DEVICES
LAN
SECURITY
APPLIANCES
PAN
INFRASTRUCTURE
AUTOMATION
IoT
SMARTPHONE +
DEVICES
PERIPHERALS
SAFETY
TOYS
REMOTES
WEARABLES

Data Driven Decision Suppor

- Decision Support system
- Assessment / Strategies
- Data Rendering, visual analytics
  - Business Intelligence
- Data Processing
- Data aggregation, Storage, indexing
- Data Ingestion

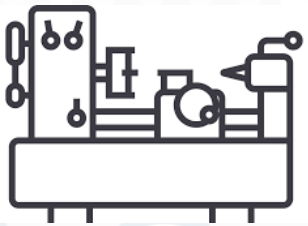


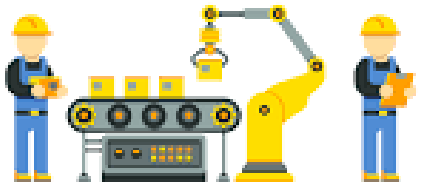
Avoiding to have a collection of verticals









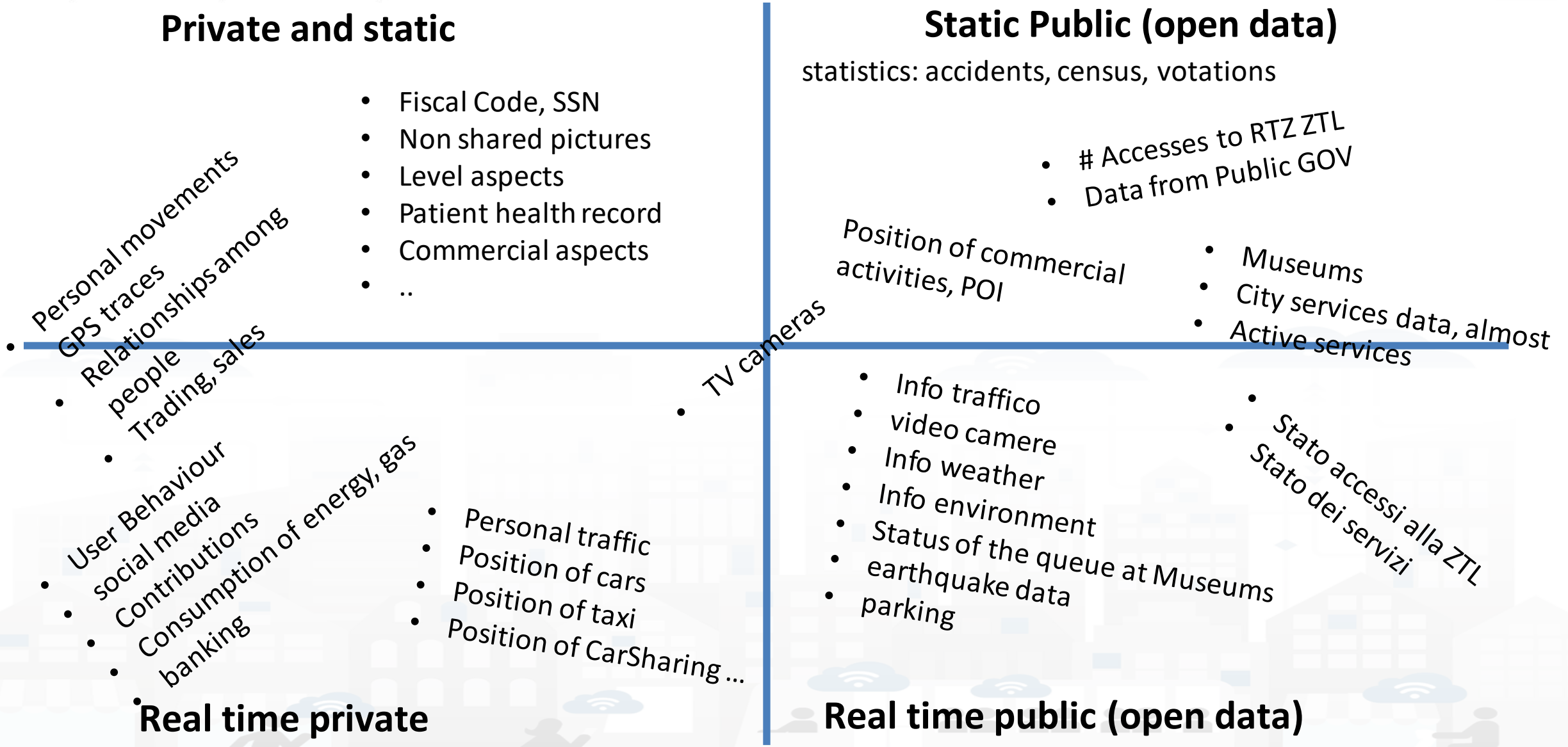


Simplifying the development and integration of verticals

Integrated Data Platform

- **Produce value from data**
  - Stimulate virtuous behavior, influence Users!
  - put in action Strategies
- **Data Exploitation performing**
  - predictions, reasoning, business intelligence, ..
  - users behavior analysis, decision support system, ..
  - Control Room, Real Time Monitoring tools, ….
- **Aggregate & integrate data**
  - Multiple protocols from operators, ….
  - open data, IOT, sensors, internet of everything, cloud, mobile devices, Wi-Fi, social media, ...



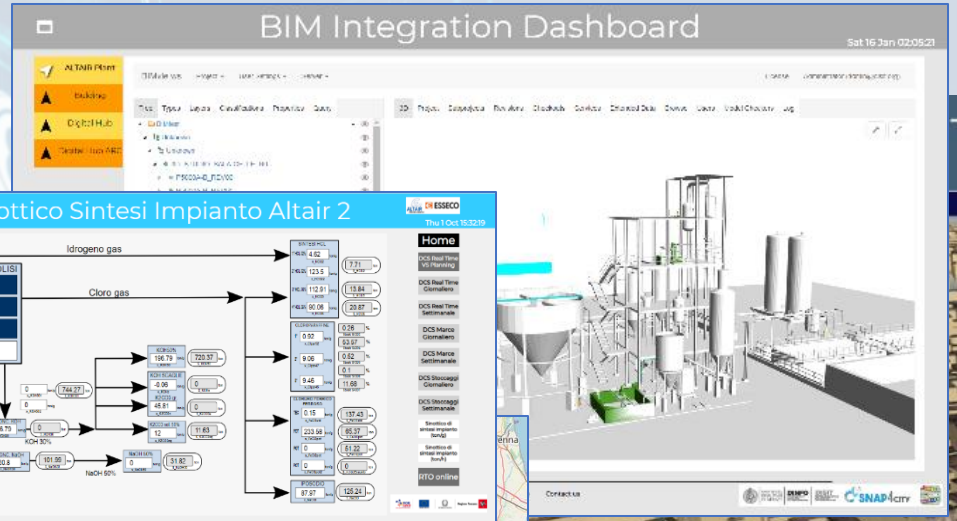

Private and static
Fiscal Code, SSN
Non shared pictures
Level aspects
Patient health record
Commercial aspects
..
Personal movements
GPS traces
Relationships among people
Trading, sales
User Behaviour
social media
Contributions
Consumption of energy, gas
banking
Personal traffic
Position of cars
Position of taxi
Position of CarSharing ...
Real time private
Static Public (open data)
statistics: accidents, census, votations
Accesses to RTZ ZTL
Data from Public GOV
Position of commercial activities, POI
Museums
City services data, almost
Active services
TV cameras
Info traffico
video camere
Info weather
Info environment
Status of the queue at Museums
earthquake data
parking
Stato accessi alla ZTL
Stato dei servizi
Real time public (open data)

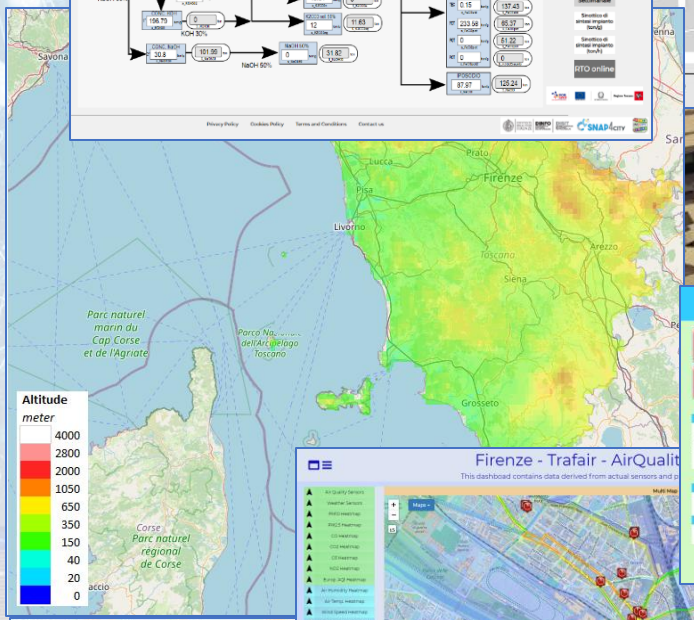
High Level Types

Snap4City (C), October 2026

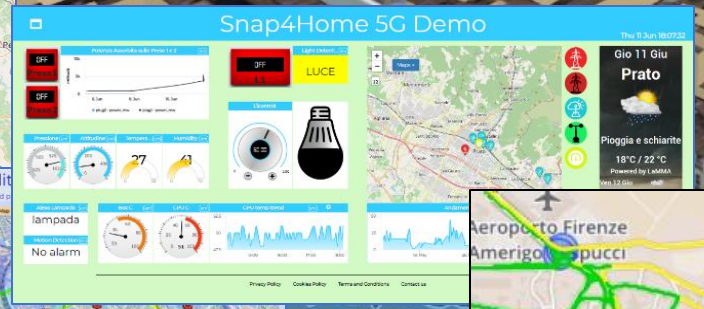
- POI, IOT Devices, shapes,..
  - FIWARE Smart Data Models,
  - IoT Device Models
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, any kind..
- traffic flow, typical trends, ..
- Vector fields + heatmaps, ..
- trajectories, events, workflow, ..
- 3D Models, BIM, Digital Twins, ..
- OD Matrices of several kinds, ..
- Dynamic icons/pins, ..
- Synoptics, animations, ..
- KPI, personal KPI,..
- social media data, TV Stream,
- routing, multimodal, constraints, ..
- scenarios, ….
- etc.





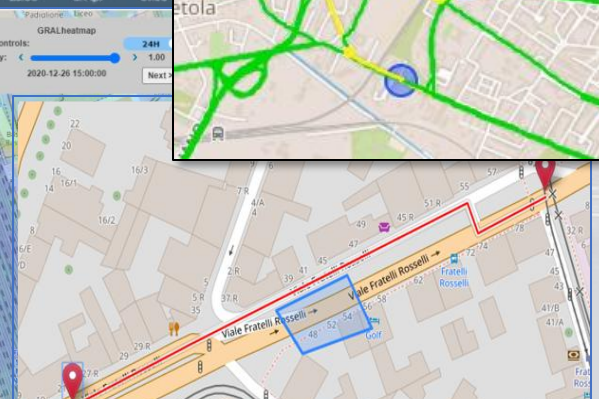












Standards and Interoperability

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, OBD2, Proximus, ..
- **IoT model:** FIWARE Smart Data Model, Snap4City IoT Device Models
- **General**: HTTP, HTTPS, TLS, Rest Call, SNMP, TCP, UDP, SOAP, WSDL, FTP, FTPS, WebSocket, WebSocket Secure, GML, WFS, WMS, WCS, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP, VMS Milestone, TIM, HERE, OGC, ….
- **Formats**: JSON, GeoJSON, XML, CSV, GeoTIFF, OWL, WKT, KML, SHP, db, XLS, XLSX, TXT, HTML, CSS, SVG, IFC, XPDL, OSM, Enfuser FMI, Lidar, glTF, GLB, DTM, GDAL, Satellite, D3 JSON, …
- **Database**: Open Search, MySQL, Mongo, HBASE, SOLR, SPARQL, ODBC, JDBC, Elastic Search, Phoenix, PostGres, MS Azure, ..
- **Industry**: OPC/OPC-UA, OLAP, ModBUS, RS485, RS232,..
- **Mobility**: DATEX, GTFS, Transmodel, ETSI, NeTEx, ..
- **Social**:Twitter, FaceBook, Telegram, ..
- **Events**: SMS, EMAIL, CAP, RSS Feed, ..
- **OS**: Linux, Windows, Android, Raspberry Pi, Local File System, AXIS. ESP32. etc.

https://www.snap4city.org/65

What About a Time Series

IOT Device



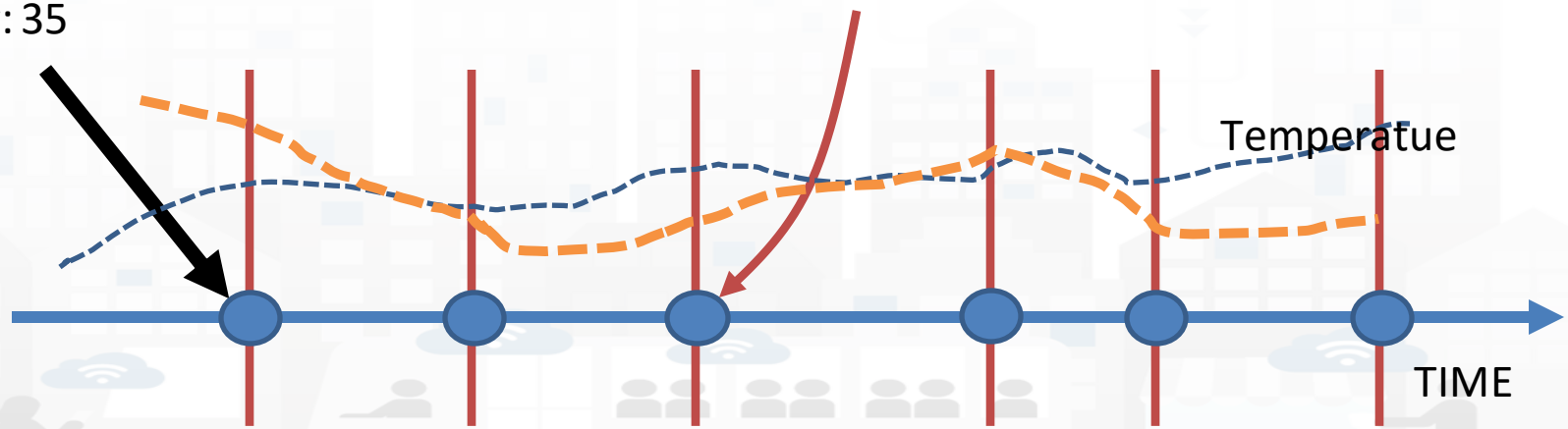
Entity: IOT Device

Sends a message

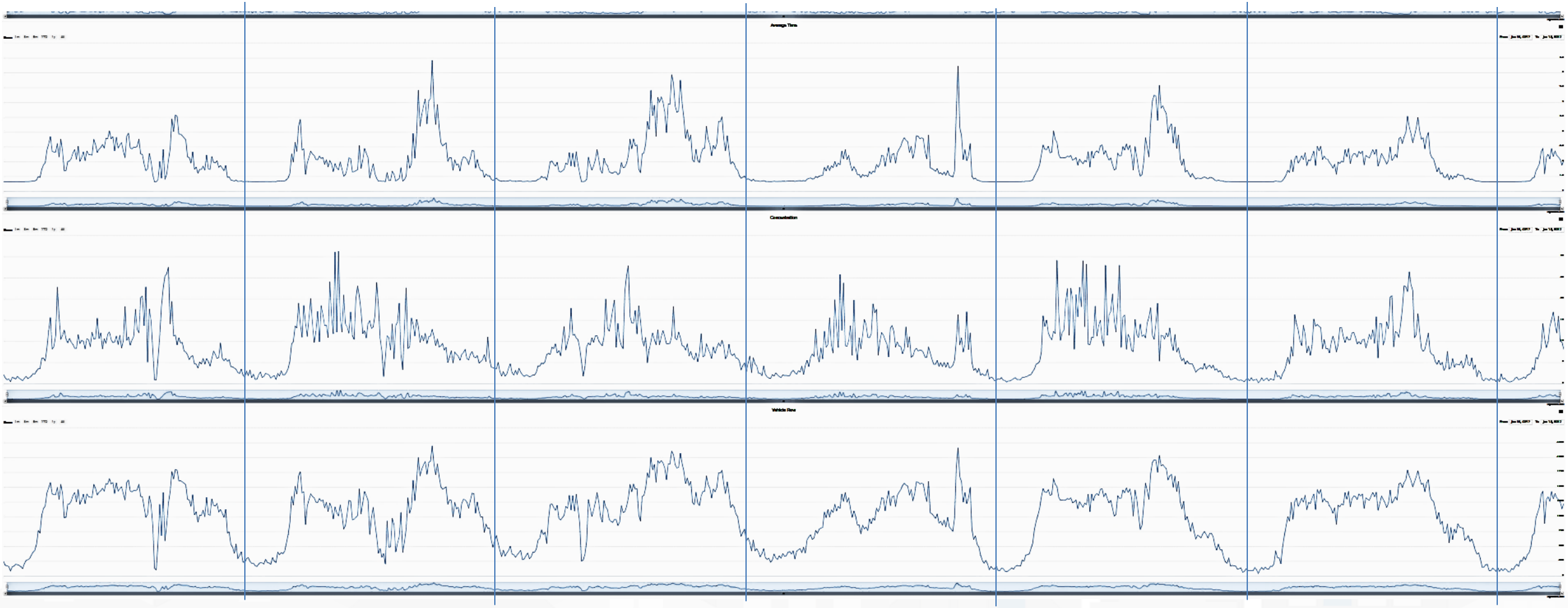
Message (
timestamp: 02-04-2020 at 10:30,
Temperature: 29.34,
Humidity: 35
)

dateObserved	Temp	Humidity
02-04-2020 10:30	34.5	23
02-04-2020 10:40	36.5	24
02-04-2020 10:50	36.0	22.5

- A set of data coming from an Entity (may be a device, an action, etc.) with multiple values become a time series of values for the Entity.
  - For example: taking a new measure every 10 minutes (Red Lines)
  - Non regular rates can be valid data as well.
- Each new measure in Snap4City is conventionally time located in «dateObserved», which has to be **Unique.**
  - **Only one message per dateObserved is allowed**



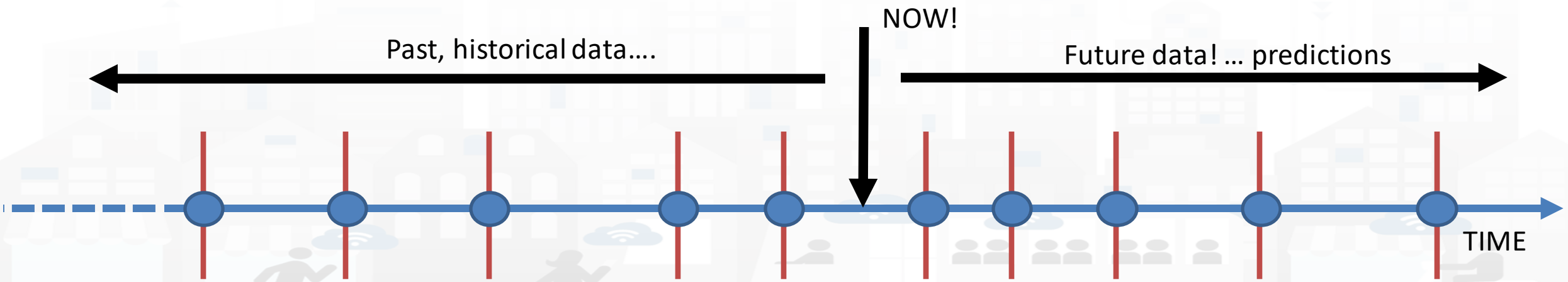
Traffic Flow data



- Day by day traffic flow, on the week data from 3 sensors

Time Series: they are data streams

- As soon as you have a variable changing over time → time series
  - You are ready to get Future data, may be arriving in PUSH
  - Recall and store historical data as well, but they have to be
    - recalled in PULL with some process taking from API, database,..



A time series

The messages posted on Entity Instances / IoT Devices can produce different effects on time series.

Omitting the message would allow the broker to reuse the last data to fill it, as for V5, which appear

- valid in all messages on graphs
- With holes in tables

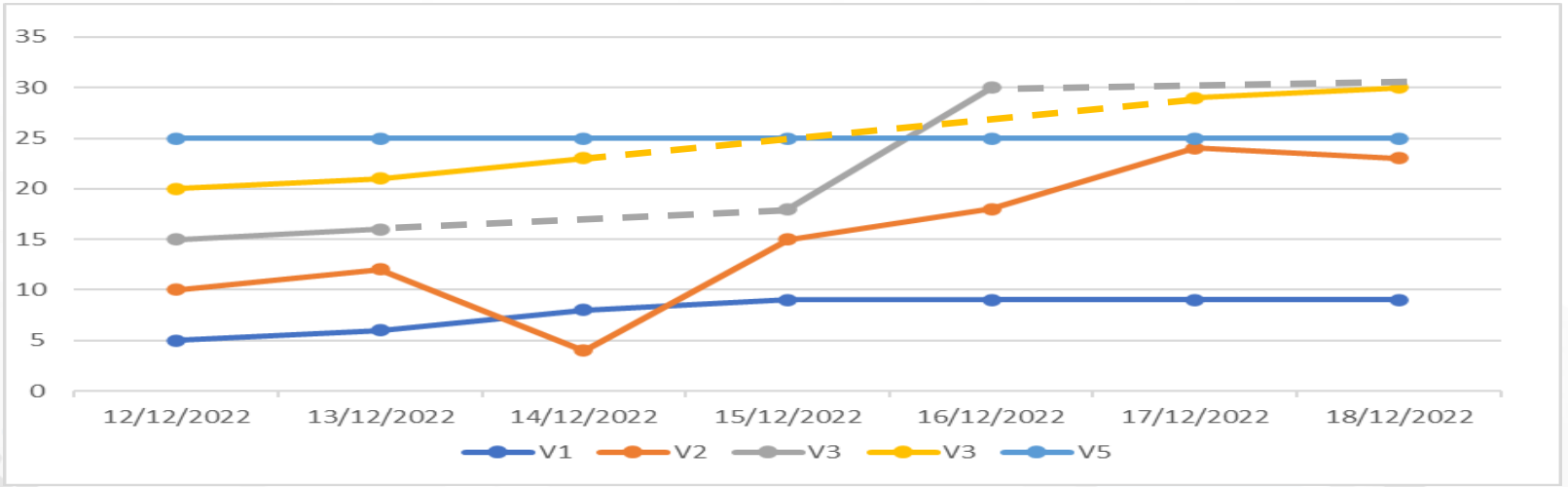
Putting null values (as in V3) would produce a missing data and thus would lead to create:

- interpolate line on graphs: dashed are actually continuous lines in Dashboards
- Empty values in the tables

device42 Entity Messages over time

Color for missed

12-12-2022	13-12-22	14-12-22	15-12-22	16-12-22	17-12-22	18-12-22
V1: 5	5	6	8	9	9	9
V2: 10	10	12	4	15	18	24
V3: 16	15	16	null	18	30	null
V4: 20	20	21	23	null	null	29
V5: 25	25	25	25	25	25	25

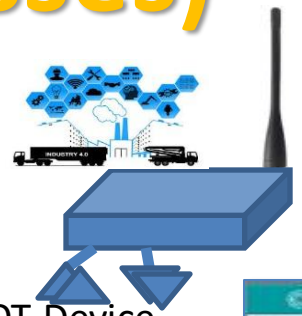


Data Indexing & Semantic Data Indexing

- **Structured:** JSON, XML, database, CSV, excel, etc.
- **Non structural Textual**, multilingual, NLP (Natural Language Processing)
  - For social media data, but also for metadata, descriptions
- **With:**
  - **Temporal** → Historical data, real time data, predictions
  - **Semantic:** relationships among entities.
  - **Spatial**, **geographical**, geo-reversing → Knowledge Base
    - Around a point, along a line/path, near a path, into a polyline, etc.
  - **Data Values** different data type (Data Lake/normalization), data unit, etc. → the so called IOT shadowing of Azure, AWS
    - Relating to Knowledge Base reciprocally

Data Collection, ingestion (processes)

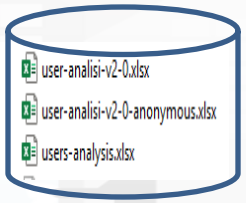
- **Data**
  - Open and private: Open Data: CKAN
    - licensing, private, GDPR
  - Static vs Real time
  - Any protocol, any standard: Push and Pull
  - Any format
- From **observations and milestones**:
  - sensors, database, KPI, etc.
- From **legacy services** of in-place operators, API, WS, FaaS, ..
  - External Services: call of any kind
  - MicroServices, MicroApplications
  - Local databases
- From **users, customers, ..**:
  - participated processes, feedback, Apps, etc.
  - Crawling web pages, etc.





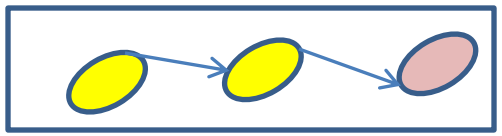


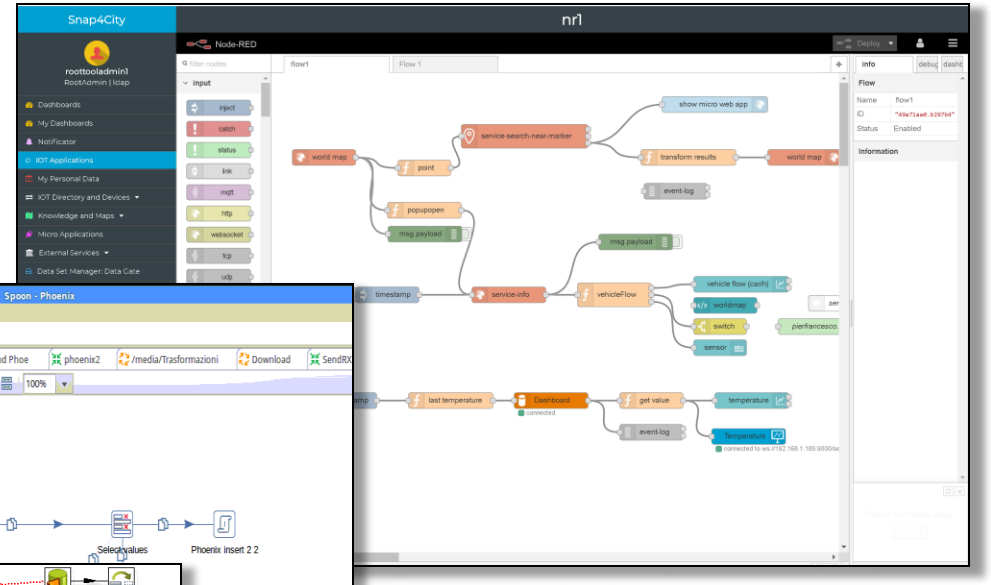


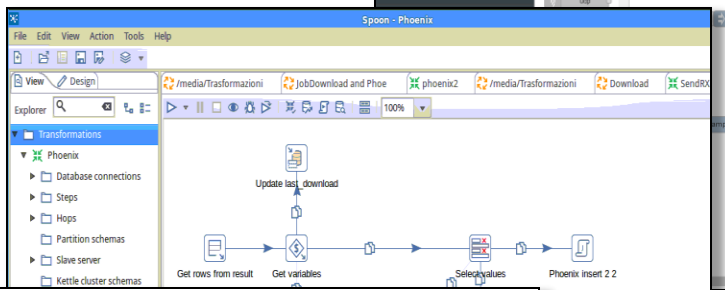


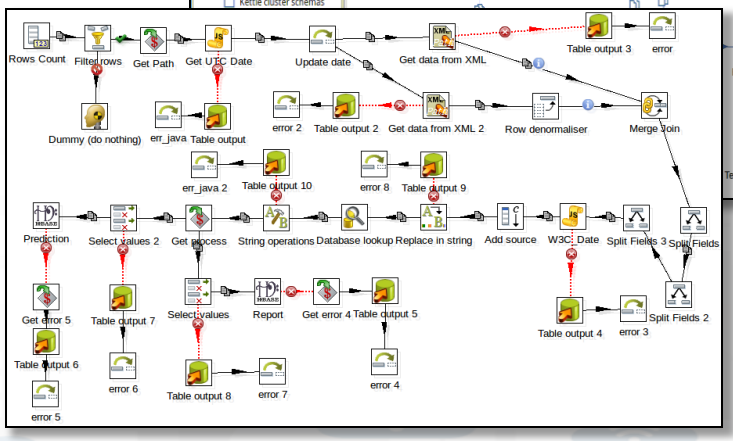
Data processing: ETL/ELT

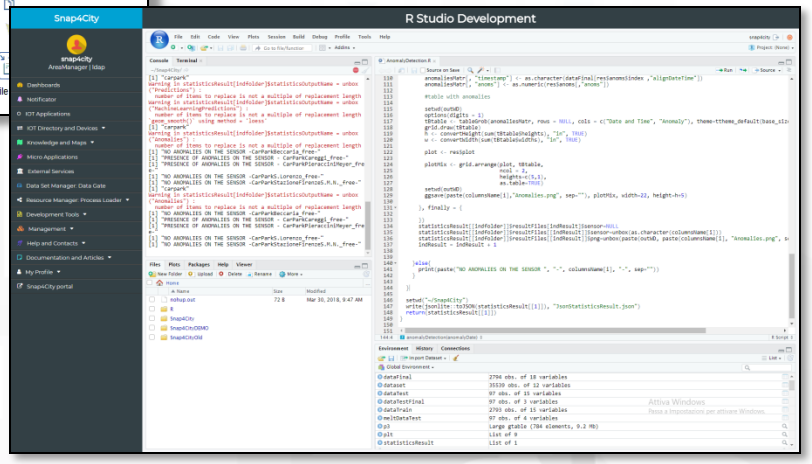
- **Data analytics**
  - Periodic or event driven
    - On demand
  - Data transformation
    - ETL: extract transform load
    - ELT: extract load transform
  - Control Flow, data transform
    - Node-RED: Node.JS
- **For example**:
  - Assessment/monitoring
  - Predictions
  - Anomaly detection
  - Simulations
  - Etc.







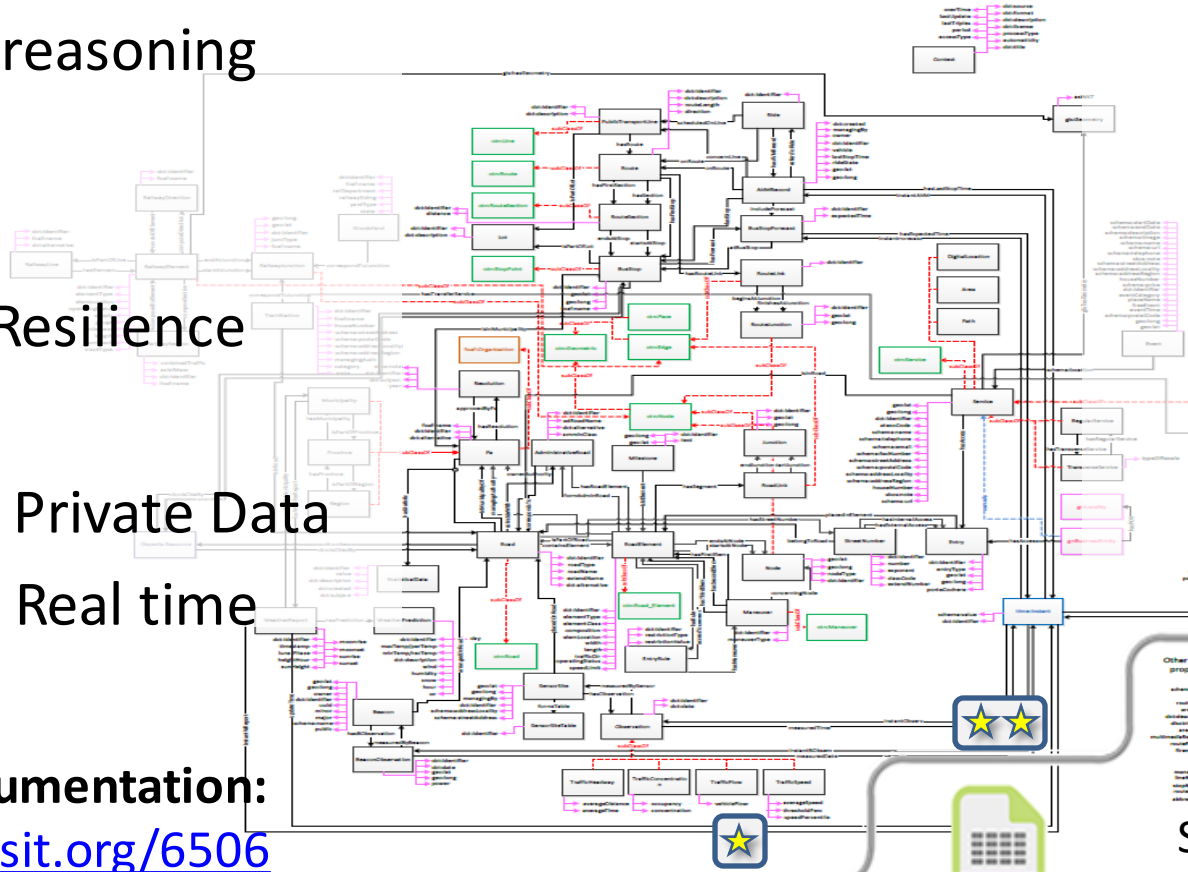




Km4City: Knowledge Base

- **Multiple DOMAINS**
- Geospatial reasoning
- Temporal reasoning
- Metadata
- Statistics
- Risk and Resilience
- Licensing
- Open and Private Data
- Static and Real time
- IOT/IOE

- Street-Guide
- Mobility and transport
- Points of interest
- Sensors, IOT, …
- Energy
- Administration
- Citations from strings
- ..



Big Data Tools

LOD and reasoners

Ontology Documentation:
http://www.disit.org/6506
http://www.disit.org/6507
http://www.disit.org/5606
http://www.disit.org/6461

Schema: http://www.disit.org/km4city/schema
RDF version: http://www.disit.org/km4city.rdf

RDF stores as NoSQL database

- All in terms of Triples
  - <Subject><Predicate><Object>
  - «cat» «is a specialization of» «animal» // generic definition for the ontology
  - // instances of the knowledge base
    - «micu» «is an instance of» «cat»
    - «leg1» «is part of the» «table»
    - «carl» «is belong to class» «5c»
    - «carl» «is child of» «frank»
    - «frank» «is father of» «carl»
  - Etc….

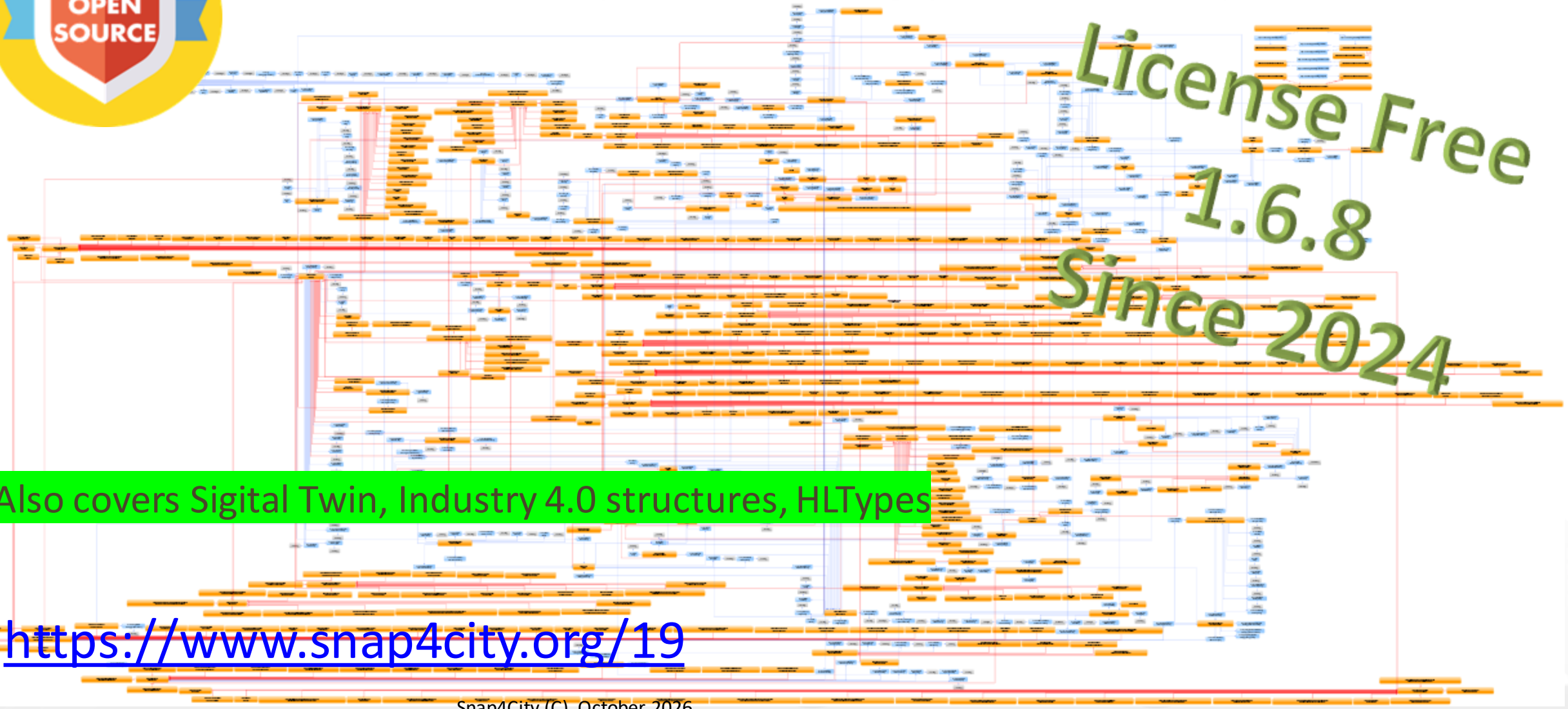
Km4City Ontology elements 1.6.8



- **DCTERMS**: for metadata Dublin Core Metadata Initiative
- **FOAF**: friends of a friends
- **Good Relation**: entities relationships
- **iot-lite**: IOT Vocabuary
- **OTN**: Ontology of Transportation Networks
- **OWL-Time**: time reasoning
- **SAREF** Smart Appliances REFerence extension for building devices available at https://saref.etsi.org/saref4bldg/
- **Schema.org** for people and organizations
- **SSN**: Semantic Sensor Network Ontology (see https://www.w3.org/TR/vocab-ssn/
- **WGS84** Datum of Geo-Objects
- **GTFS**, General Transit Feed Specification, and **Transmodel**, for public transport infrastructures: lines/rides time schedules, real-time records, paths, etc.;
- **BOT**: Building Topology Ontology. https://w3c-lbd-cg.github.io/bot/
- **S4CITY**: SAREF extension for Smart City. https://saref.etsi.org/saref4city/v1.1.2/

Smart-city Ontology km4city

100% OPEN SOURCE



Also covers Sigital Twin, Industry 4.0 structures, HLTypes

https://www.snap4city.org/19

The Ontology Pipeline

From Business Language to Enterprise Knowledge Graph

Turn complex data into meaningful business knowledge — with the right tools at every step.



Same data. Shared meaning. Bigger impact!

Connect
Understand
Reuse
Create value

Business Meaning › **Technical Semantic Integration** › **Enterprise Knowledge Graph**

1 BUSINESS VOCABULARY / GLOSSARY

Agree on business names, definitions and synonyms with domain experts.

Term
Definition
Synonyms
...

Tools

collibra, Purview, atlan, ellie.ai, Alation, erwin, Semarchy

2 METADATA & STANDARDS

Describe and govern data and metadata consistently.

DCAT
Dublin Core
SKOS
...

Tools

collibra, Purview, DataHub, Open Metadata, atlan, Apache Atlas, Alation, Informatica

3 TAXONOMY

Organize concepts into broader / narrower hierarchies.

Standards

SKOS | ISO 25964 | OKG

Tools

TopBraid EDG, poolparty, protégé, VocBench, NeOn Toolkit

4 THESAURUS / CONTROLLED VOCABULARY

Define preferred and alternative labels and related terms.

Preferred term — Alternative label — Concept — Broader term — Narrower term

Standards

SKOS | SKOS-XL

Tools

TopBraid EDG, poolparty, protégé, OpenRefine, VocBench

5 ONTOLOGY

Define classes, properties, relationships and constraints.

Property — Relationship — Class — Constraint — Axiom

Standards

RDF | RDFS | OWL | SHACL

Tools

ANZO, protégé, TopBraid EDG, poolparty, VocBench, Stardog, ontop

6 SEMANTIC MAPPING & DATA INTEGRATION

Map and integrate data from enterprise systems to ontology concepts.

Structured (SAP, Snowflake, DB)
Semi-structured (JSON, CSV, APIs)
Unstructured (Documents, PDFs)
→ R2RML / RML SPARQL

Tools

snowflake, CortexAI, ALTAIR, ANZO, talend, Fivetran, MuleSoft, ontop, RMLMapper, nifi

7 KNOWLEDGE GRAPH

Connect ontology with enterprise data into a queryable semantic graph.

Invoice

Tools

neo4j, Amazon Neptune, Stardog, GRAPHWISE, TigerGraph, ArangoDB, ALTAIR

Standards layer: SKOS | RDF | RDFS | OWL | SHACL | SPARQL | R2RML / RML | DCAT | Dublin Core | ISO 25964

Enterprise data sources

\+ \+ Other enterprise sources (databases, files, APIs, ...)

› **Semantic Layer / Enterprise Knowledge Graph** ›

Business value

BI | Analytics | AI Agents

Non structured data

- **Textual Data coming from:**
  - Social media posts
  - Dialogue with users, posts, blob, complains, emails
  - Documents, manuals, slides, web pages
  - Media: images, video, audio, drawings, etc.
- **Non structured can be processed by**
  - AI NLP solutions, BERT, LLM, LLM RAG, etc.
    - *See webinar of the 14 October 2025, 15:00*

UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

Data Lake vs Data Warehouse

https://www.snap4City.org https://www.Km4City.org

Parte: 3 (2024)



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Architettura di base Big Data, IOT, Industry 4.0

Data Sources

Transatio ns sys, sensors Social media, ws, etc.

Data Stream analysis

Spark, Storm, Kafka

Big Data Cluster

HDFS, noSQL

Data Transformation

ETL, NIFI

Indexing

SOLR, Elastic search

Data Analytics

R, TF, …

Search and Query

Facet, cluster

Visual Analytics

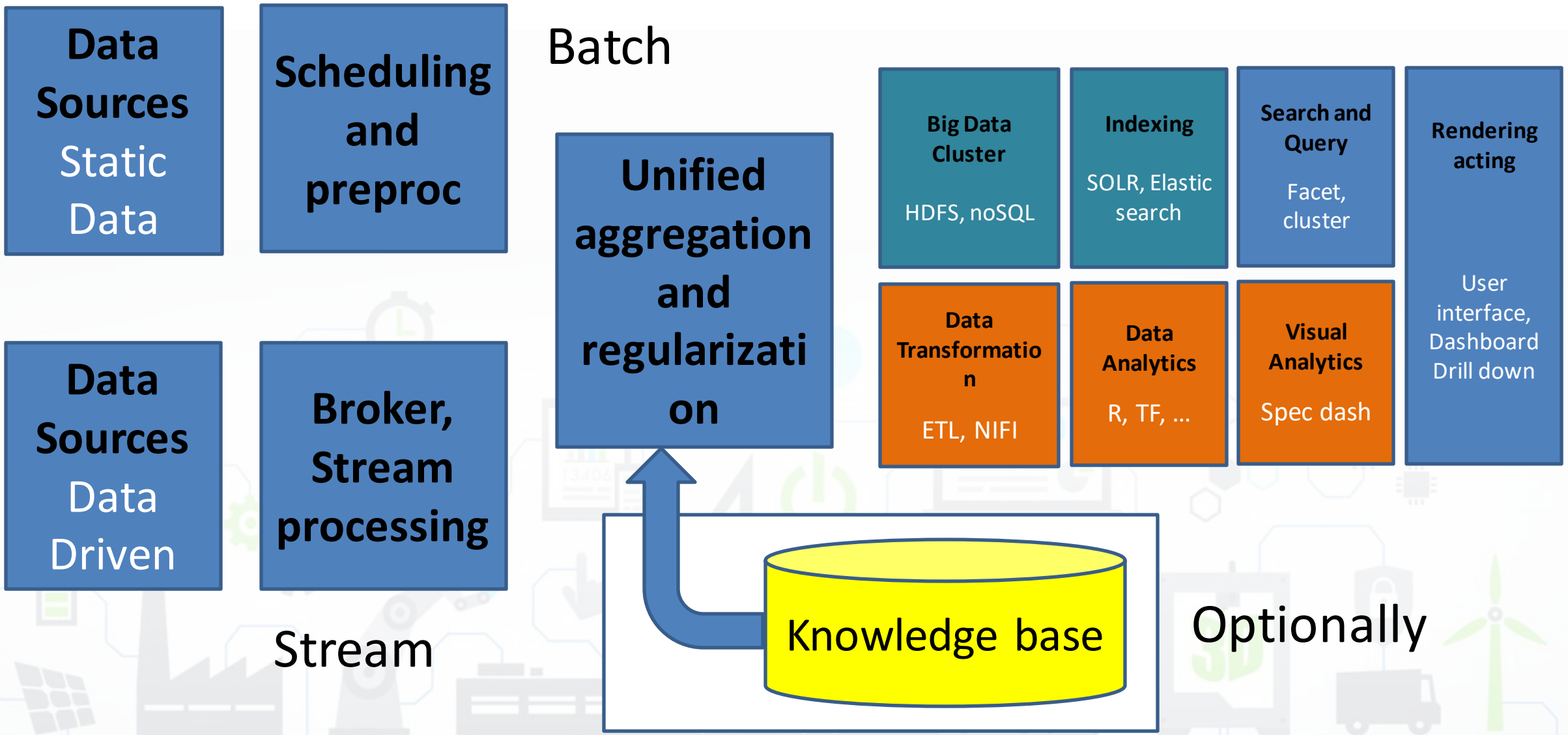
Spec Dash

Rendering acting

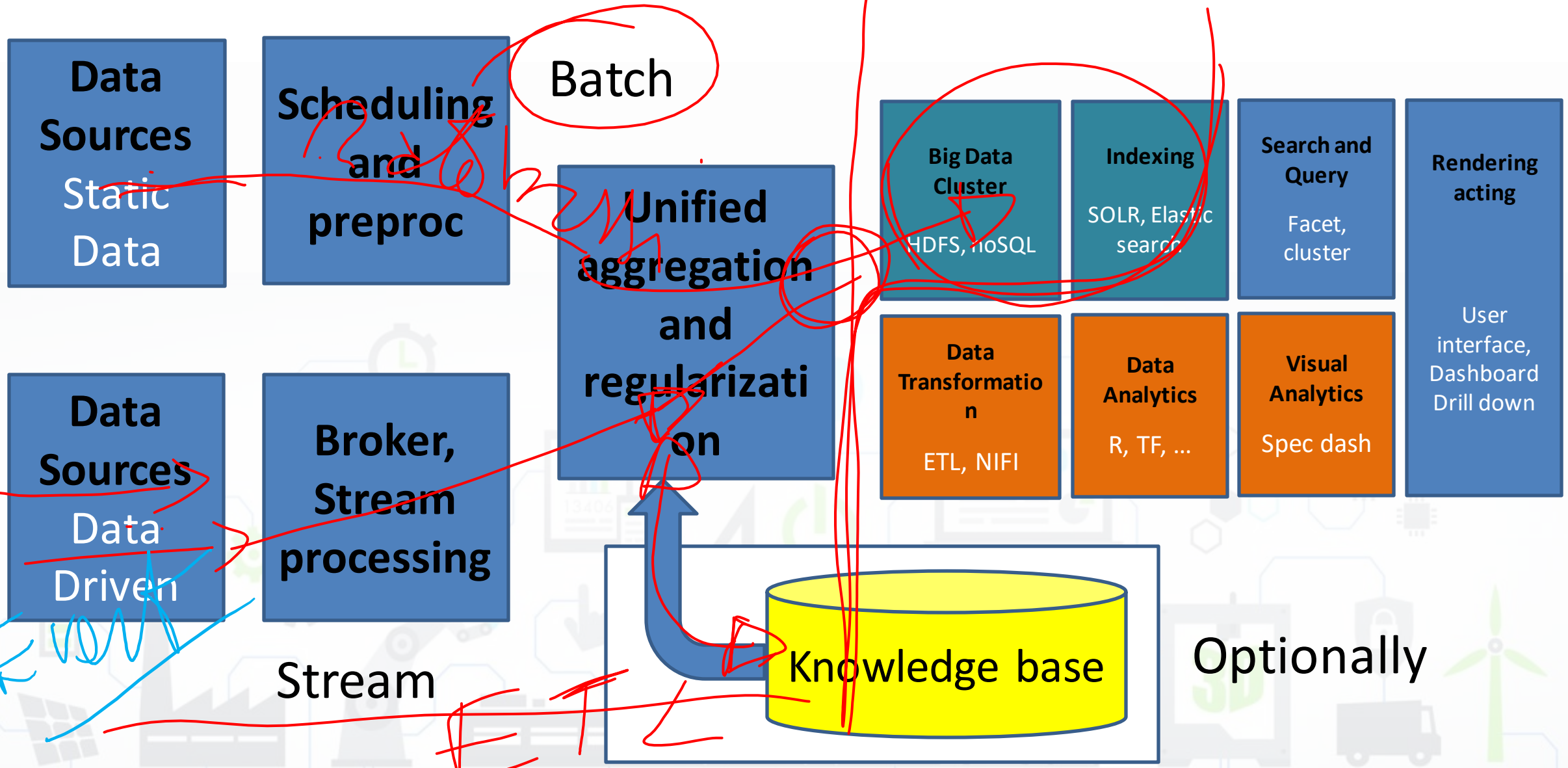
User interface, Dashboard Drill down

Data Management: security, privacy, licensing, etc.

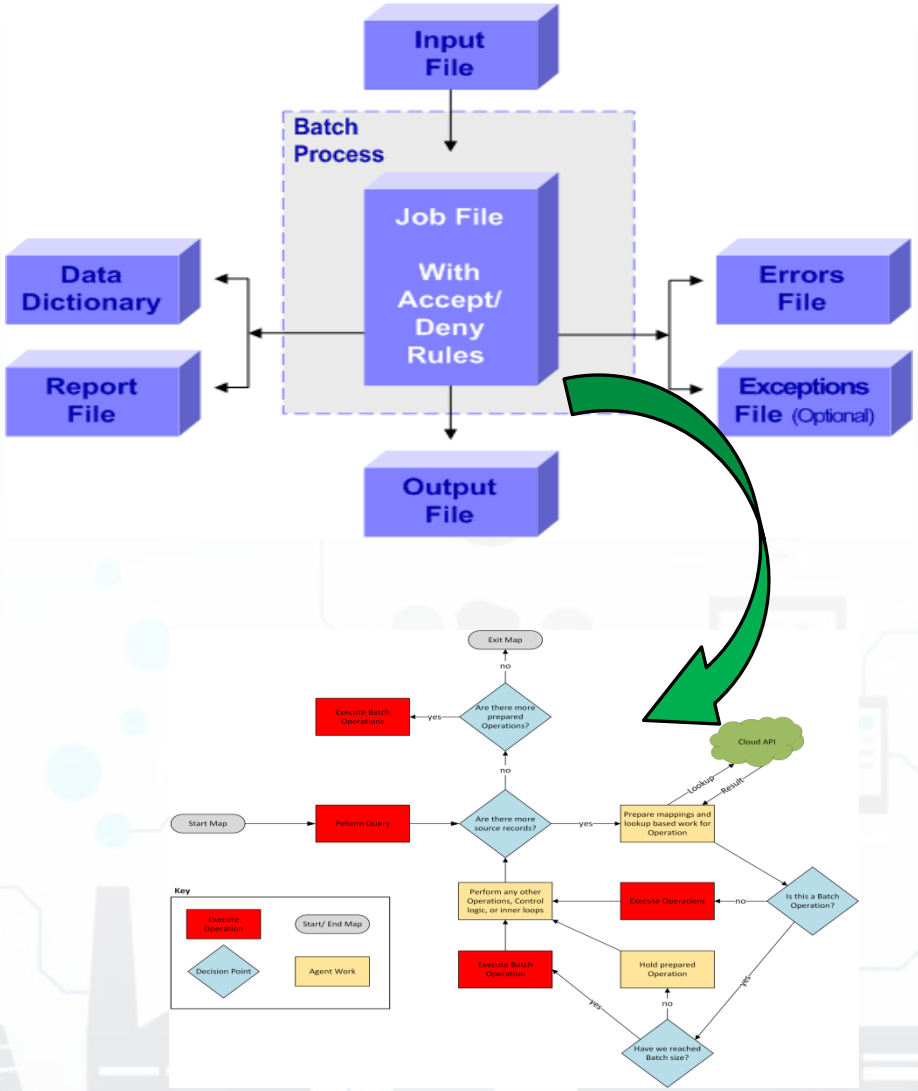
Lambda Architecture



Lambda Architecture

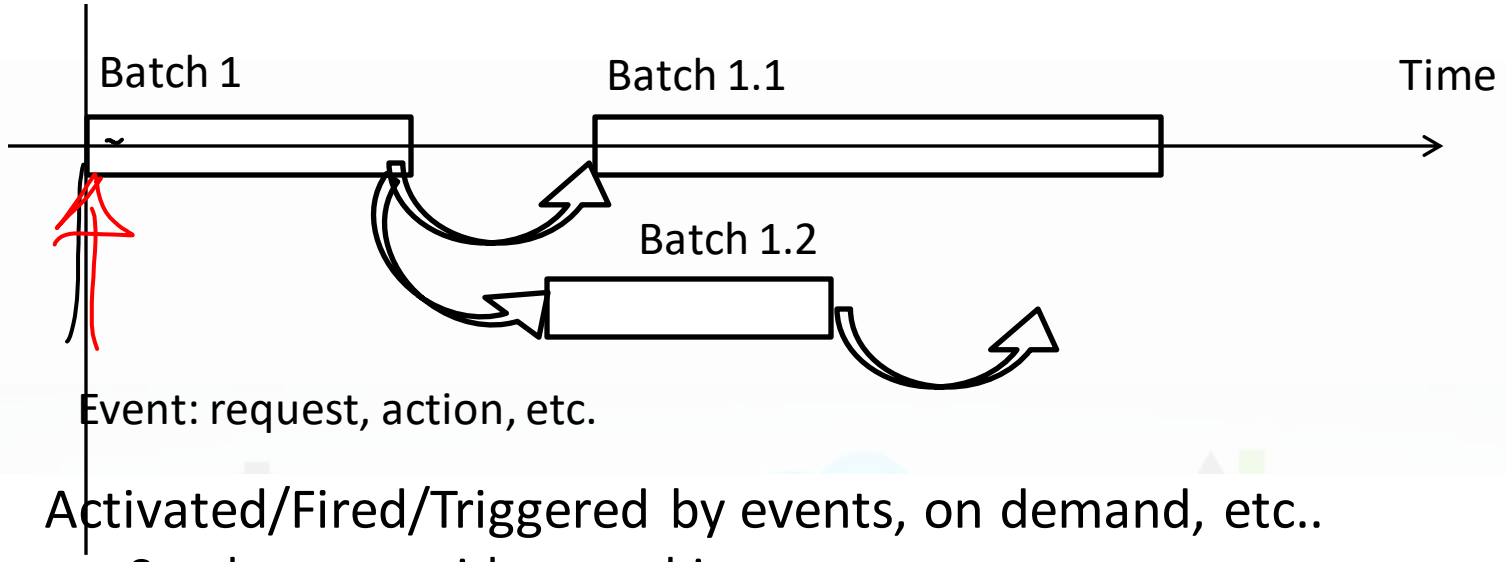


Batch Processing



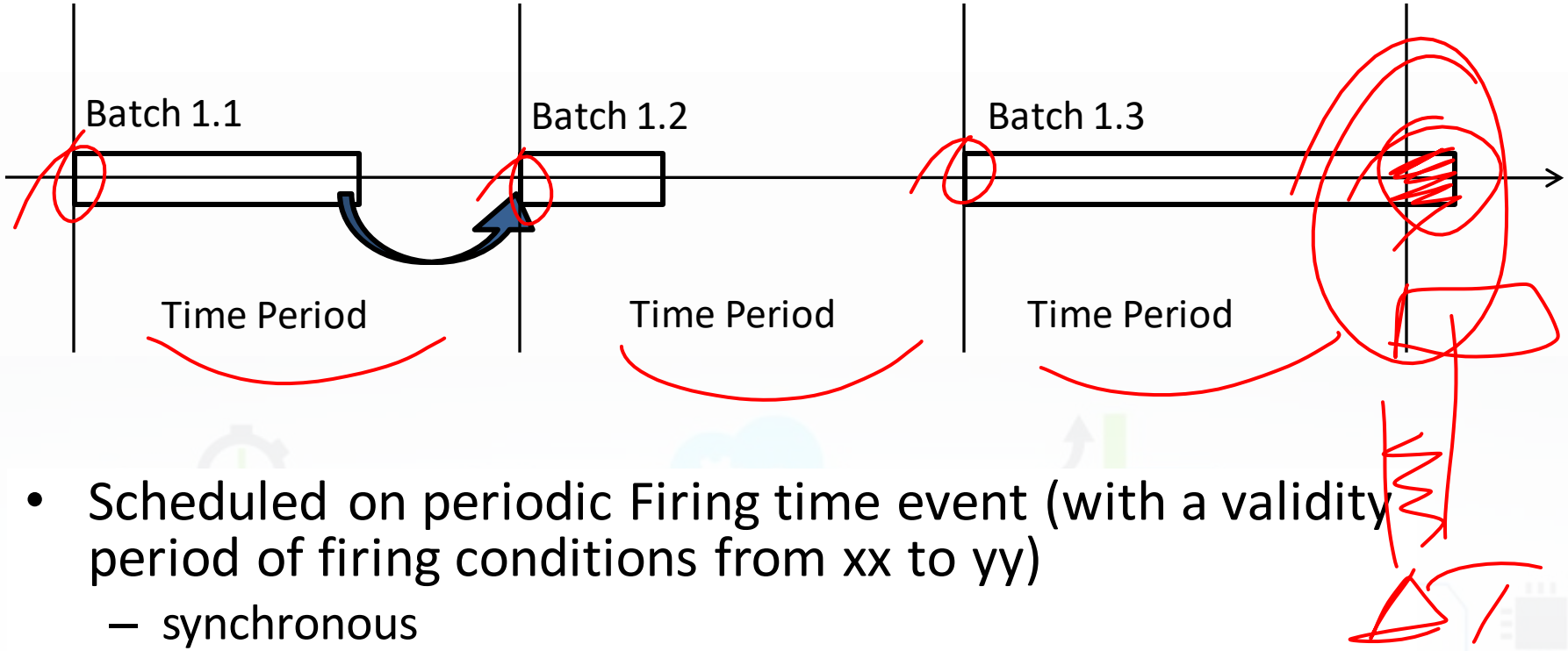
- Script language
- Smilar to workflow or flowchart
- Sequence of Commands
- Intermediate status on disk or memory
- Executed command driven:
  - On demand, sporadically
  - Periodically

aPeriodic Batch processing



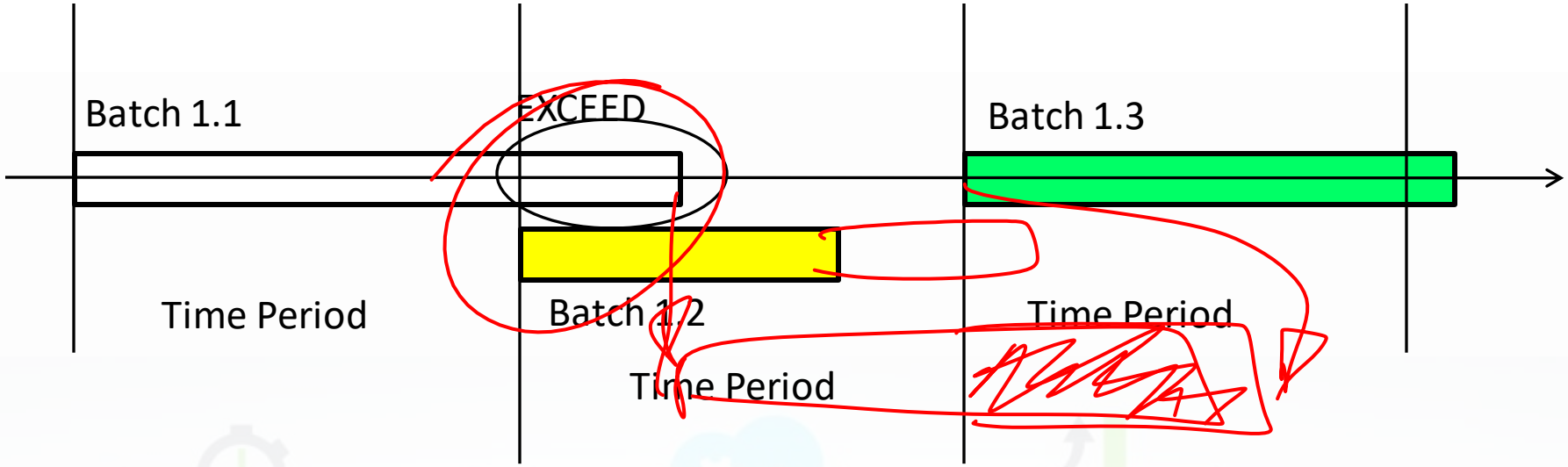
- Activated/Fired/Triggered by events, on demand, etc..
  - Synchronous with something
  - chained or not
- May fire/generate (ask to do or directly do) other jobs/batches:
  - on the same or different computers
  - Identical or different
- Activation may be asked to a third party manager
- Duration of execution depending on data !

Periodic Batch processing



- Scheduled on periodic Firing time event (with a validity period of firing conditions from xx to yy)
  - synchronous
- Execution time duration depending on data or other..
  - Execution may exceed the Time Period
- Each single execution MAY or MAY NOT depend on the preceding one

Periodic Batch processing



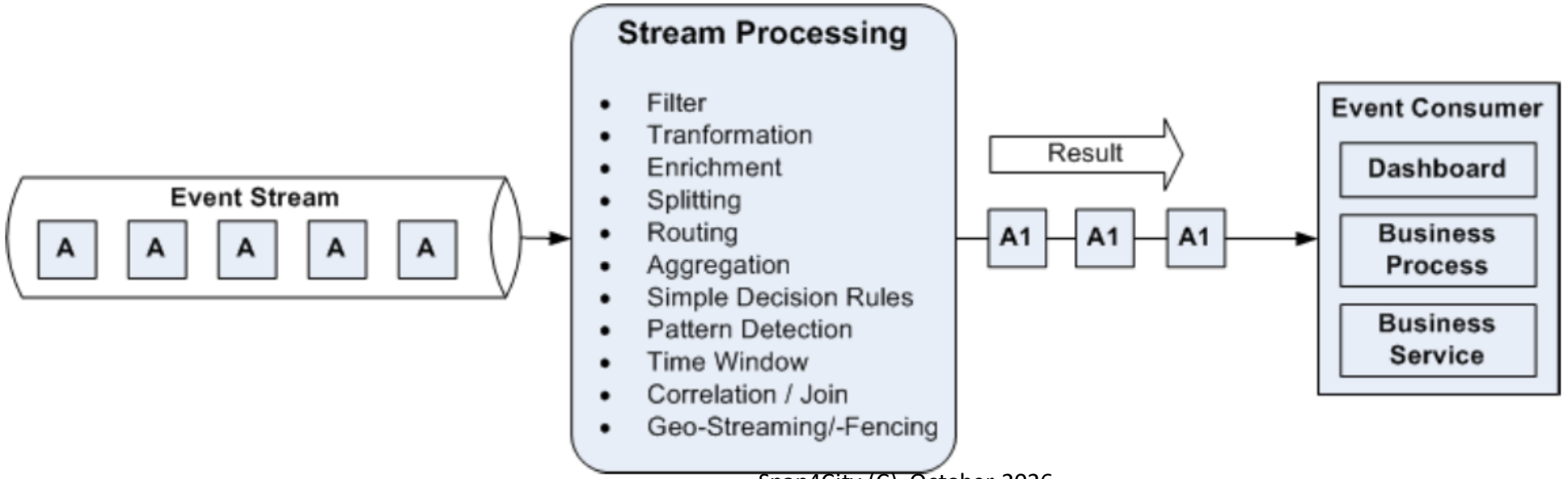
- If the Execution Time Duration exceeds the Time Period
  - A) the successive execution (Batch 1.2) is overlapped (yellow)
    - If it happens systematically: the number of tasks grow indefinitely consuming all resources → until crash
  - B) the successive execution (Batch 1.2) is canceled to wait for the next one (Batch 1.3, green),
    - skipping the second execution, Batch 1.2

Stream Processing

- paradigma di programmazione parallela
  - Detto anche di real time processing
- Lavora con:
  - Dati parziali e non su tutto l'insieme dei dati.
  - Per esempio: valutare il contenuto spettrale di un segnale:
    - Su tutto il segnale
    - Su una finestra temporale di 30 secondi, per ogni secondo un nuovo valore, small delay/latency, (but present , see pipeline)
- L'attivazione del processo corrisponde spesso all'arrivo del dato nello stream, nella pipeline,
  - si ha sincronizzazione e comunicazione in un solo colpo.
  - Tipicamente una sequenza di azioni semplici attivate da
    - l'arrivo delle condizioni e dei dati per calcolare i risultati
    - ed in modo asincrono
    - tipicamente senza avere necessità di memorizzare il dato
  - → elimina alcuni problemi della programmazione parallela.

Stream Processing

- Example on languages
  - SISAL (Streams and Iteration in a Single Assignment Language)
  - CUDA (Compute Unified Device Architecture) for NVIDIA GPU, SIMD
- Applications:
  - IOT, media recognition, log processing, social media enrichment, indexing,



Main Purpose

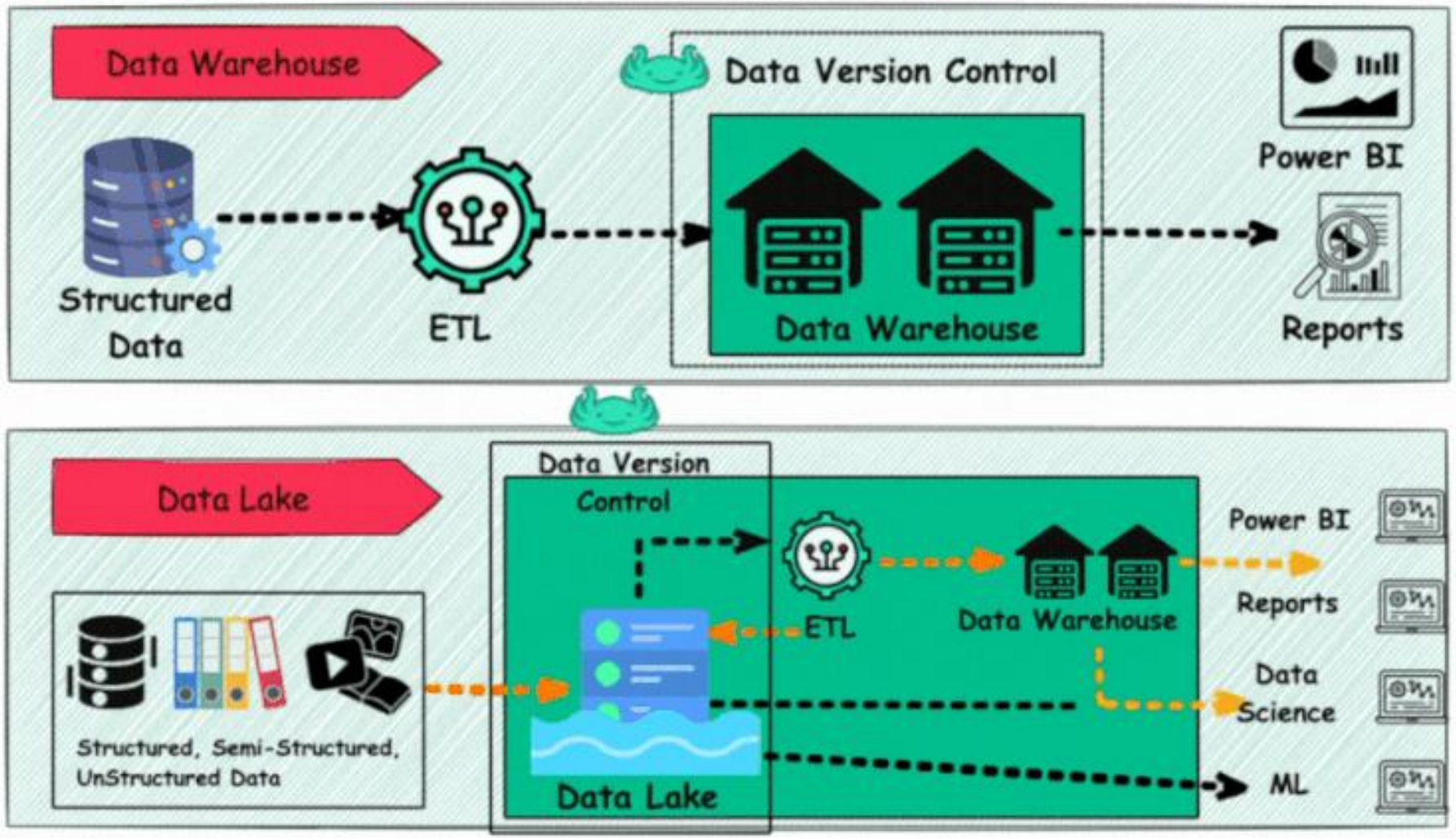
- To store a large amount of data, **big data**, and they can be **structured and un-structured**, several different kind of data:
  - **Direct Data**: Time series, geolocated data, events, shapes, measures, social media posts, video, files, logs, etc.
    - Most of them may have multiple features, e.g.: geolocated events with shape
  - **Derived Data**: predictions, typical trends, trajectories, flows, heatmaps, 3D reconstructions, traffic reconstruction, planning, simulations, etc.
- for **exploiting them** for producing:
  - Deductions, hints, early warning,
  - Derived Data as well, in real time

Main Functions

- **Data Extraction:**
  - gathering, harvesting, ingestion, reception in push, ….
- **Data Transformation:**
  - Adaptation, mapping, formatting, conversion, enrich
  - Cleaning or leaving as it is
- **Data Loading** and Refreshing: saving in the storage
  - As it is, converted and ready to use, etc.
- **Data Usage:**
  - As it is from Storage (faster, more rigid schema, higher volume in access)
  - Transformed on the fly (slower, more flexible, moderate volume in access)

DW vs DL

- ETL-Usage vs ELT-Usage
- DW:
  - More complex data ingestion
    - Simplify data ingestion for sporadically used data
  - Faster date usage unforeseen patterns/combinations
- DL:
  - Faster data ingestion
  - More complex data rendering since all combination are unplanned
    - Prepare data rendering for well known patterns


Data Warehouse
Data Version Control
Power BI
Structured Data
ETL
Data Warehouse
Reports
Data Lake
Data Version Control
ETL
Data Warehouse
Power BI
Reports
Data Science
ML
Structured, Semi-Structured, UnStructured Data
Data Lake

Parameters	Data Lake	Data Warehouse
Task	can contain all data and data types; it empowers users to access data prior the process of transformed, cleansed and structured.	Data warehouses can provide insights into pre-defined questions for pre-defined data types.
Processing time	empower users to access data before it has been transformed, cleansed and structured. Thus, it allows users to get to their result more quickly compares to the traditional data warehouse.	Data warehouses offer insights into pre-defined questions for pre-defined data types. So, any changes to the data warehouse needed more time.
Position of Schema	Typically, the schema is defined after data is stored. This offers high agility and ease of data capture but requires work at the end of the process	Typically schema is defined before data is stored. Requires work at the start of the process, but offers performance, security, and integration.
Data processing	use of the ELT (**Extract Load Transform**) process.	Data warehouse uses a traditional ETL (**Extract Transform Load**) process.
Complain	Data is kept in its raw form. It is only transformed when it is ready to be used.	The chief complaint against data warehouses is the inability, or the problem faced when trying to make change in in them.
Key Benefits	They integrate different types of data to come up with entirely new questions as these users not likely to use data warehouses because they may need to go beyond its capabilities.	Most users in an organization are operational. These type of users only care about reports and key performance metrics.

https://www.guru99.com/data-lake-vs-data-warehouse.html

Pros and Cons

- **Data Lake**
  - Original data preserved, structured and unstructured
  - Lower costs of ingestion
  - Lower performance in the usage
  - Security: possible control at source
  - More difficult to extend in usage, simpler in storage
  - More scientist oriented
    - Moderated results in access

- **Data Warehouse**
  - Original data transformed and prepared for mainly structured or semi-structured
  - Higher cost of ingestion
  - Higher performance in the usage
  - Security: Control on organized data
  - More difficult to extend in storage, simpler in usage
  - More Business and Purpose Oriented
    - Large volume of accesses

DWH

Data Sources Static Data

Scheduling and preproc

Batch

Unified aggregation and regularizati on

Storage

Big Data Cluster HDFS, noSQL

Indexing SOLR, Elastic search

Search and Query Facet, cluster

Rendering acting User interface, Dashboard Drill down

Data Transformati on ETL, NIFI

Data Analytics R, TF, …

Visual Analytics Spec dash

Data Sources Data Driven

Broker, Stream processing

Stream

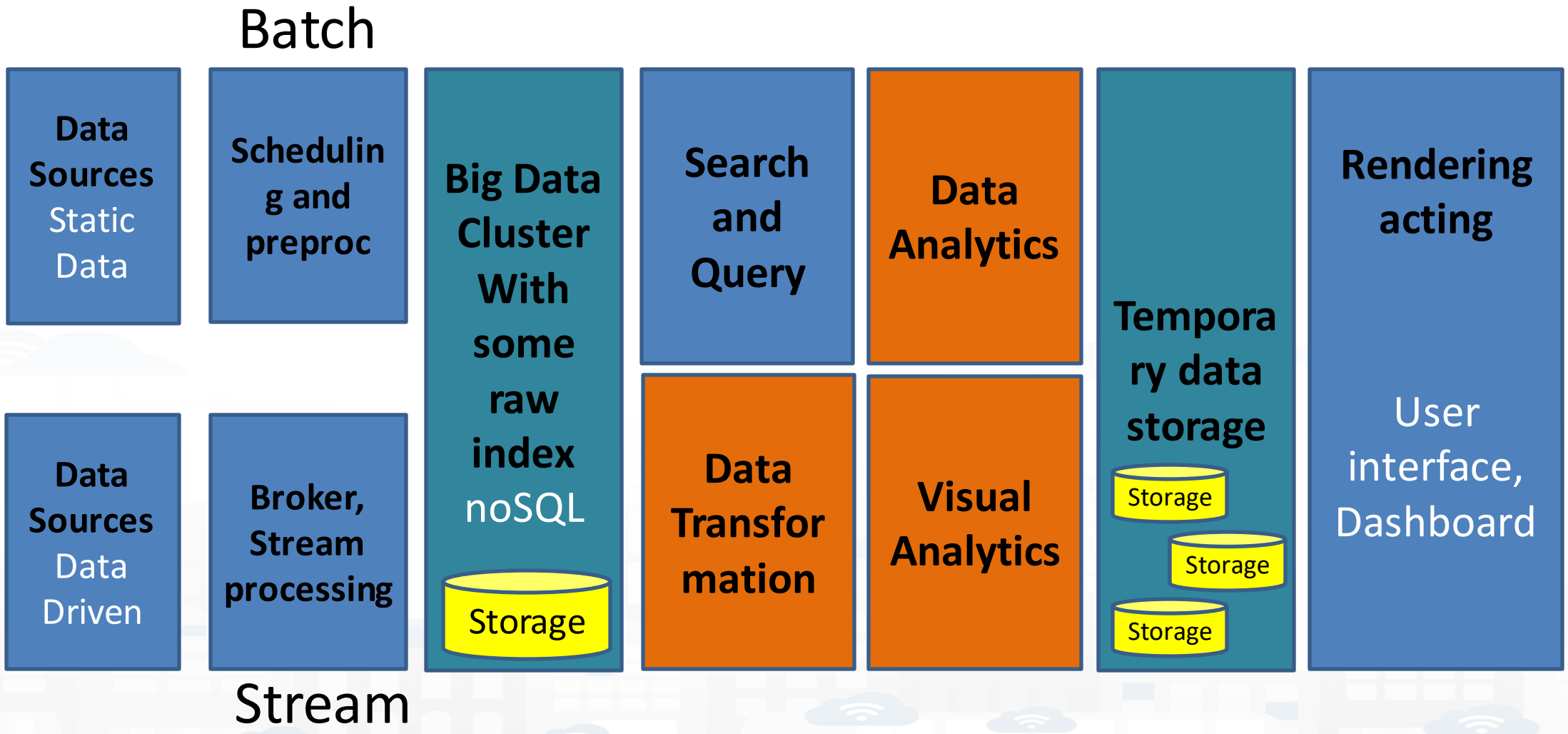
Knowledge base

Optionally

Top Cloud Data Warehouses at a Glance

	Amazon Redshift	Microsoft Azure Synapse	Google BigQuery	Snowflake Cloud Data Platform
Initial Release	2012	2016	2010	2014
Separates Storage and Compute	No	Yes	Yes	Yes
Multi-Cloud	No	No	No	Yes
Query Language	Amazon Redshift SQL	TSQL	Standard SQL 2011 & BigQuery SQL	Snowflake SQL
Elasticity	Yes - Manual	Yes – Manual and Automatic	Yes – Automatic	Yes – Automatic
MPP	Yes	Yes	Yes	Yes
Columnar	Yes	Yes	Yes	Yes
Foreign Keys	Yes	Yes	No	Yes
Transaction	ACID	ACID	ACID	ACID
Concurrency	Yes	Yes	Yes	Yes
Durability	Yes	Yes	Yes	Yes
Automation	No	No	No	No
Website	Link	Link	Link	Link
Free Trial	Yes	Yes	Yes	Yes

DL


Batch
Data Sources Static Data
Scheduling and preproc
Big Data Cluster With some raw index noSQL
Storage
Search and Query
Data Analytics
Temporary data storage
Storage
Storage
Storage
Rendering acting
User interface, Dashboard
Data Sources Data Driven
Broker, Stream processing
Data Transformation
Visual Analytics
Stream



Data Structure

Data Lake	Data Warehouse
Raw	Processed



Purpose of Data

Not yet determined	Currently in use



Users

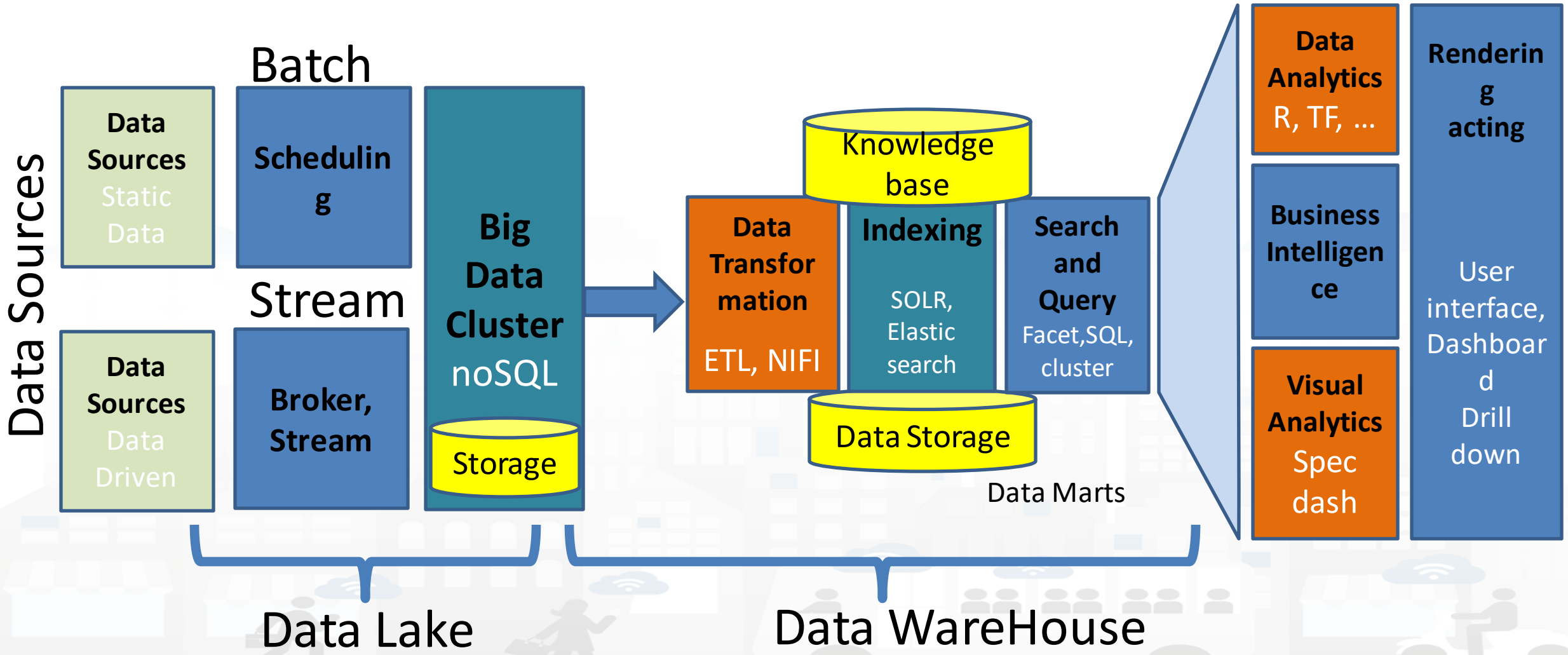
Data scientists	Business professionals



Accessibility

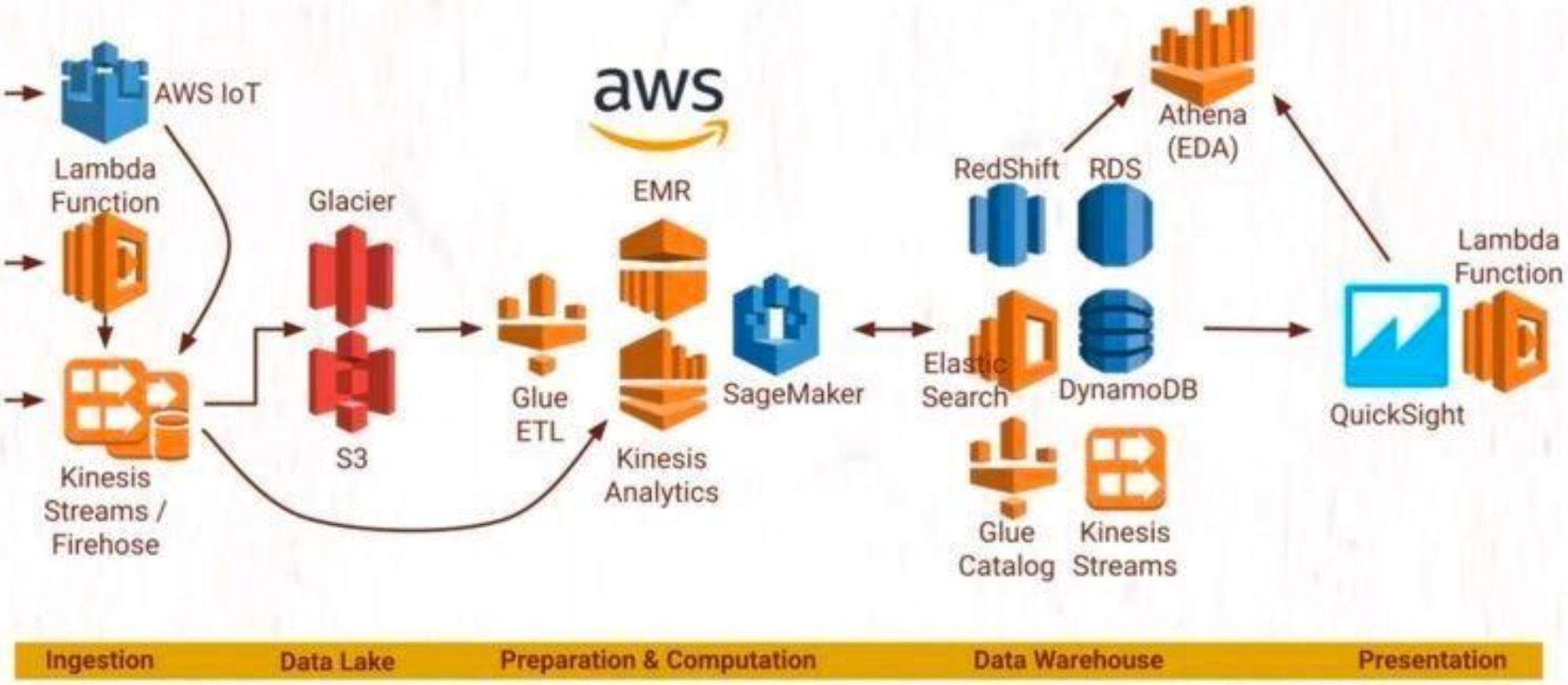
Easier to ingest and update unstructured data	More difficult to ingest and update data due to the need for uniformity and structure, but easier to consume

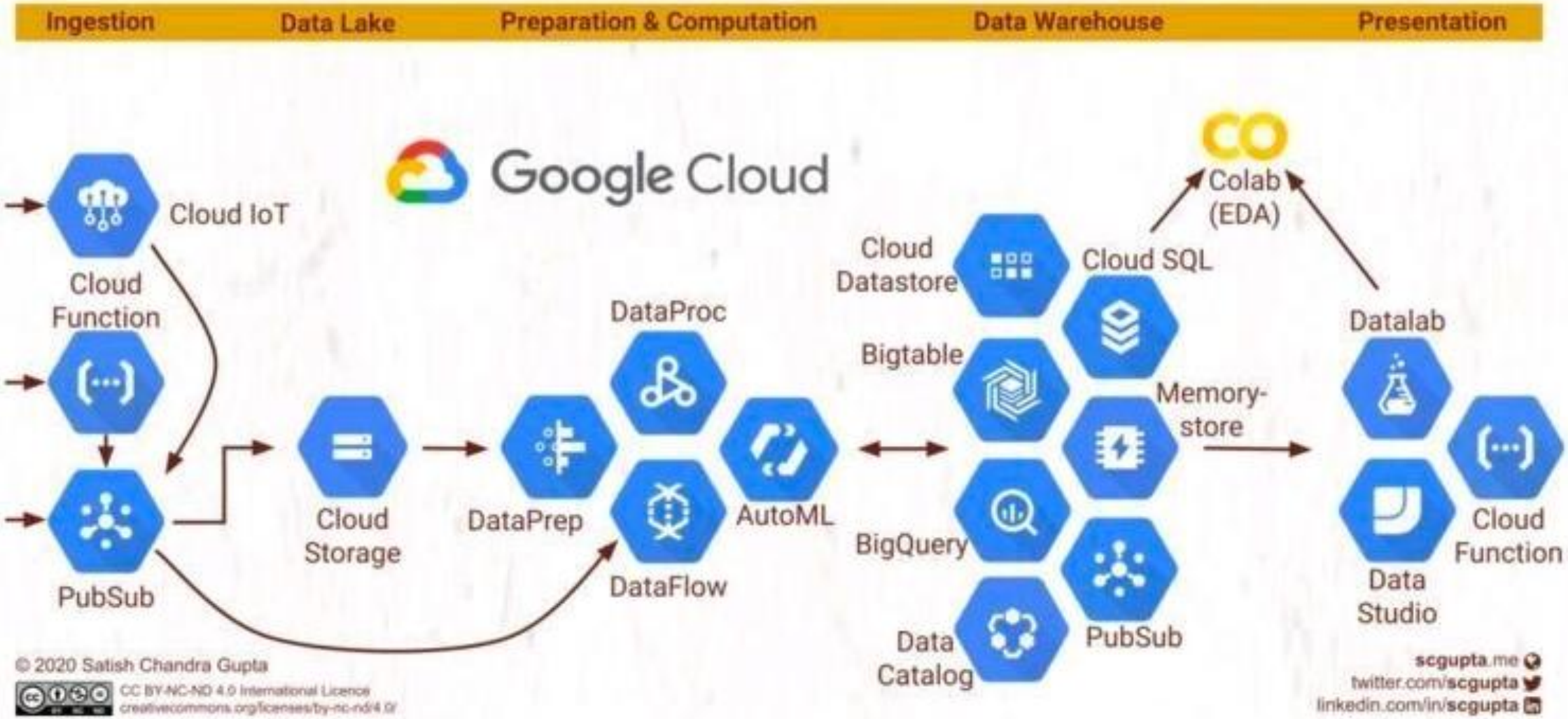
Combined Solutions

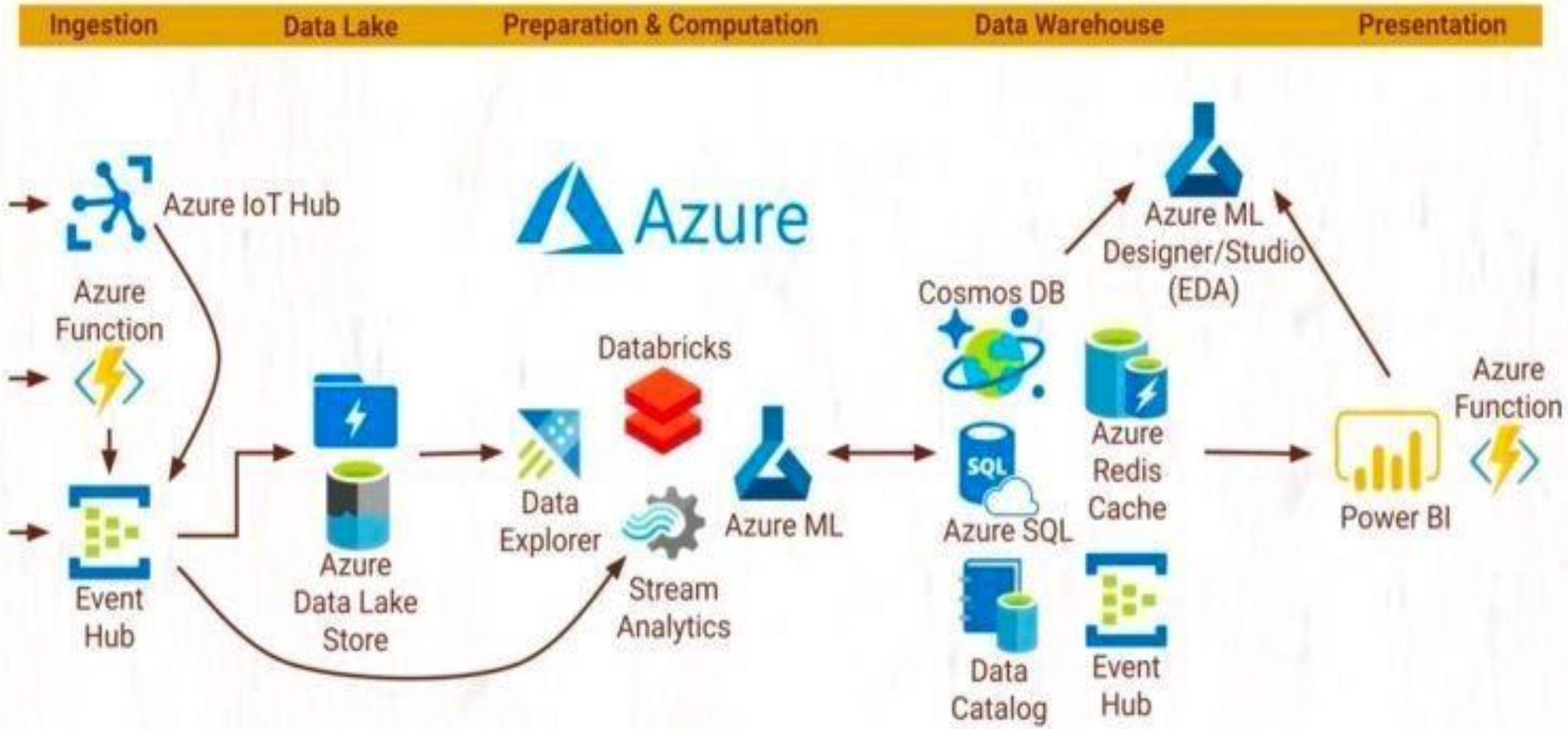


Big Data Pipelines on AWS, Microsoft Azure, and GCP

scgupta.link/big-data-pipeline




Ingestion
Data Lake
Preparation & Computation
Data Warehouse
Presentation
Google Cloud
Cloud IoT
Cloud Function
PubSub
Cloud Storage
DataPrep
DataProc
DataFlow
AutoML
Cloud Datastore
Bigtable
BigQuery
Data Catalog
Cloud SQL
Memory-store
PubSub
Colab (EDA)
Datalab
Data Studio
Cloud Function
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Ingestion
Data Lake
Preparation & Computation
Data Warehouse
Presentation
Azure IoT Hub
Azure Function
Event Hub
Azure Data Lake Store
Azure
Data Explorer
Databricks
Stream Analytics
Azure ML
Cosmos DB
SQL
Azure SQL
Data Catalog
Azure Redis Cache
Event Hub
Azure ML Designer/Studio (EDA)
Power BI
Azure Function

CLOUD COMPARISON

AWS VS. AZURE VS. GOOGLE



@simonholdorf

	aws	Azure	Google
Avalaible Regions	AWS Regions and Zones	Azure Regions	Google Compute Regions & Zones
Compute Services	Elastic Compute Cloud (EC2)	Virtual Machines	Compute Engine
App Hosting	Amazon Elastic Beanstalk	Azure Cloud Services	Google App Engine
Serverless Computing	AWS Lambda	Azure Functions	Google Cloud Functions
Container Support	Elastic Container Service	Azure Container Service	Container Engine
Scaling Options	Auto Scaling	Azure Autoscale	Autoscaler
Object Storage	Amazon Simple Storage (S3)	Azure Blob Storage	Cloud Storage
Block Storage	Amazon Elastic Block Storage	Azure Managed Storage	Persistent Disk
Content Delivey Network (CDN)	Amazon CloudFront	Azure CDN	Cloud CDN
SQL Database Options	Amazon RDS	Azure SQL Database	Cloud SQL
NoSQL Database Options	AWS DynamoDB	Azure DocumentDB	Cloud Datastore

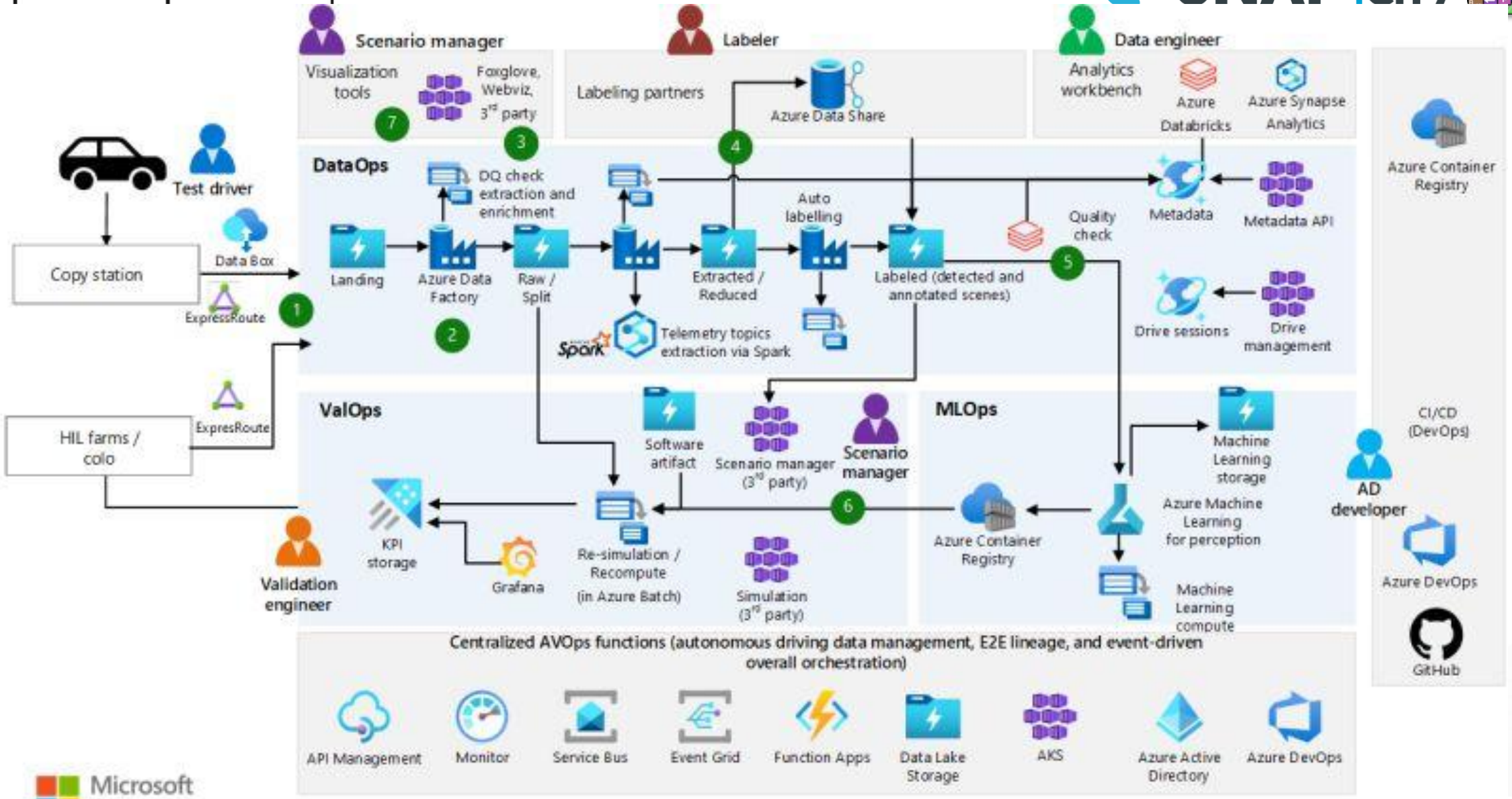
CLOUD COMPARISON

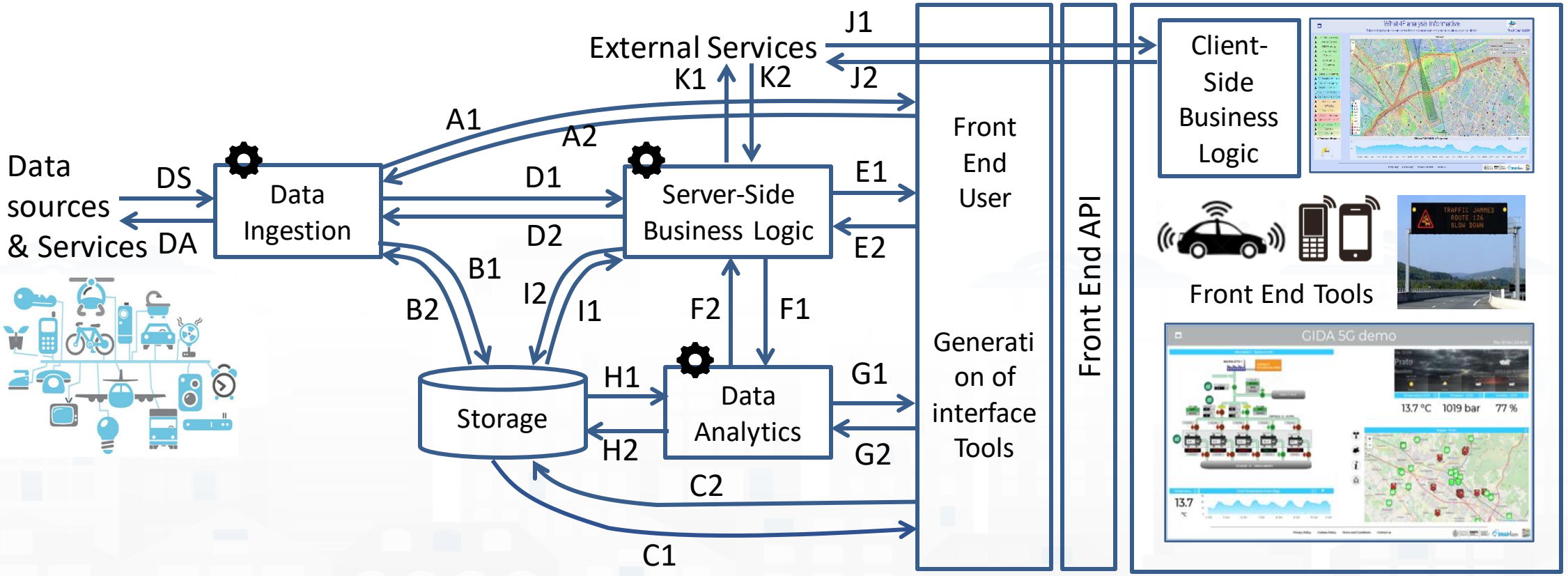
AWS VS. AZURE VS. GOOGLE



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	aws	Azure	
Virtual Network	Amazon VPC	Azure Virtual Network	Cloud Virtual Network
Private Connectivity	AWS Direct Connect	Azure Express Route	Cloud Interconnect
DNS Service	Amazon Route 53	Azure Traffic Manager	Cloud DNS
Log Monitoring	Amazon CloudTrail	Azure Operational Insights	Cloud Logging
Performance Monitoring	Amazon CloudWatch	Azure Application Insights	Stackdriver Monitoring
Administration and Security	AWS Identity and Access Management (IAM)	Azure Active Directory	Cloud Identity and Access Managament (IAM)
Compliance	AWS CloudHSM	Azure Trust Center	Google Cloud Platform Security
Analytics	Amazon Kinesis	Azure Stream Analytics	Cloud Dataflow
Automation	AWS Opsworks	Azure Automation	Compute Engine Management
Management Services & Options	Amazon CloudInformation	Azure Resource Manager	Cloud Deolyment Manager
Notifications	Amazon Simple Notification Service (SNS)	Azure Notification Hub	None


Scenario manager
Visualization tools
Foxglove, Webviz, 3rd party
Labeler
Labeling partners
Azure Data Share
Data engineer
Analytics workbench
Azure Databricks
Azure Synapse Analytics
Azure Container Registry
Test driver
Copy station
Data Box
ExpressRoute
HIL farms / colo
ExpresRoute
DataOps
DQ check extraction and enrichment
Landing
Azure Data Factory
Raw / Split
Extracted / Reduced
Auto labelling
Labeled (detected and annotated scenes)
Quality check
Metadata
Metadata API
Drive sessions
Drive management
Telemetry topics extraction via Spark
ValOps
Software artifact
Scenario manager (3rd party)
Scenario manager
KPI storage
Grafana
Re-simulation / Recompute (in Azure Batch)
Simulation (3rd party)
Validation engineer
MLOps
Azure Container Registry
Machine Learning storage
Azure Machine Learning for perception
Machine Learning compute
CI/CD (DevOps)
AD developer
Azure DevOps
GitHub
Centralized AVOps functions (autonomous driving data management, E2E lineage, and event-driven overall orchestration)
API Management
Monitor
Service Bus
Event Grid
Function Apps
Data Lake Storage
AKS
Azure Active Directory
Azure DevOps
Microsoft Azure


Data sources & Services
DS
DA
Data Ingestion
A1
A2
D1
D2
B1
B2
Storage
I2
I1
H1
H2
Data Analytics
F2
F1
Server-Side Business Logic
External Services
K1
K2
J1
J2
E1
E2
G1
G2
C2
C1
Front End User
Generation of interface Tools
Front End API
Client-Side Business Logic
Front End Tools
GIDA 5G demo

UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

IoT Architectures

https://www.snap4City.org https://www.Km4City.org

Parte: 4 (2024)



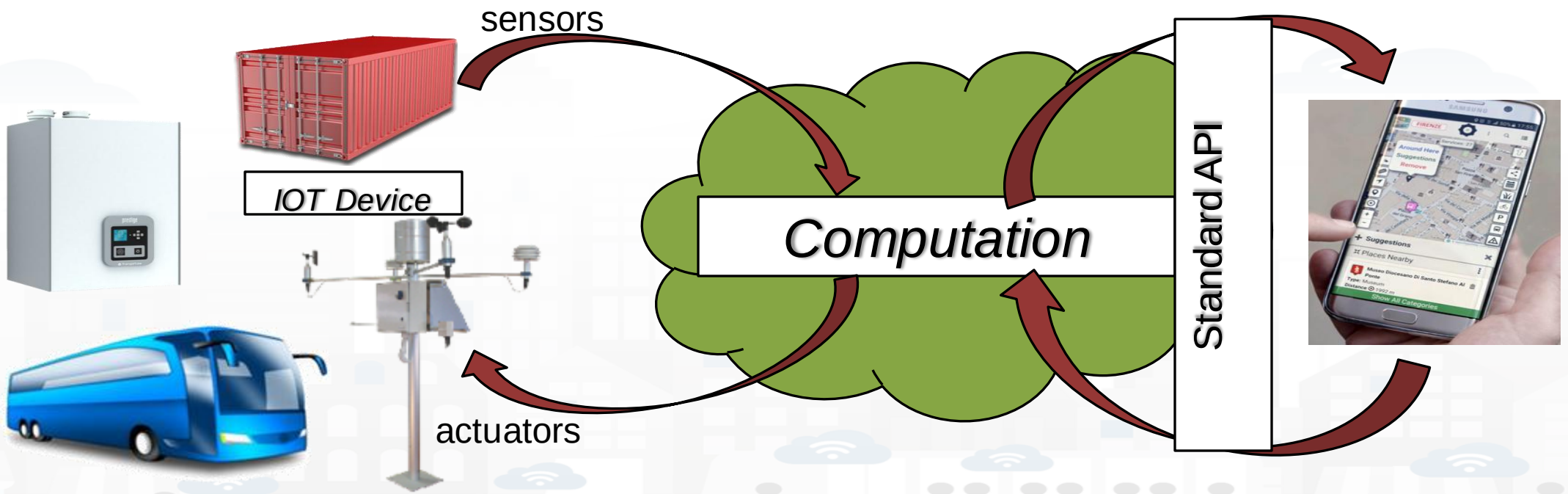
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BY NC ND

IOT Solutions



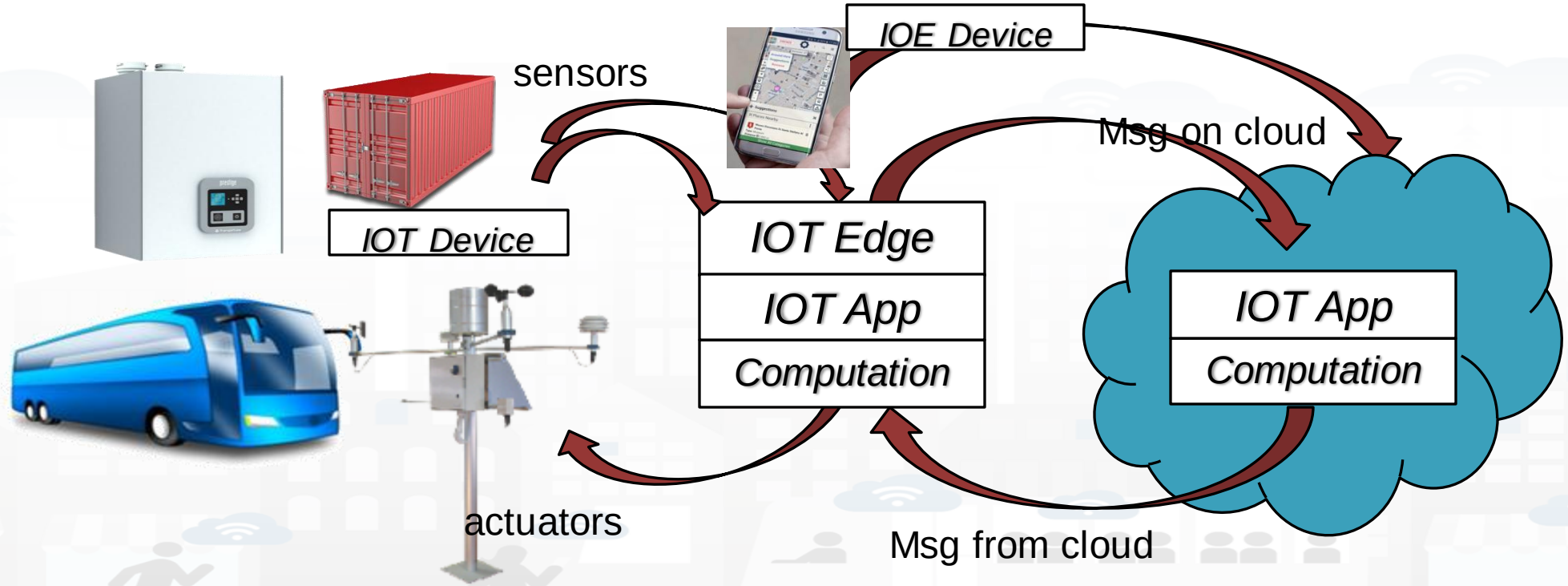
IOT Main Concept

- 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.

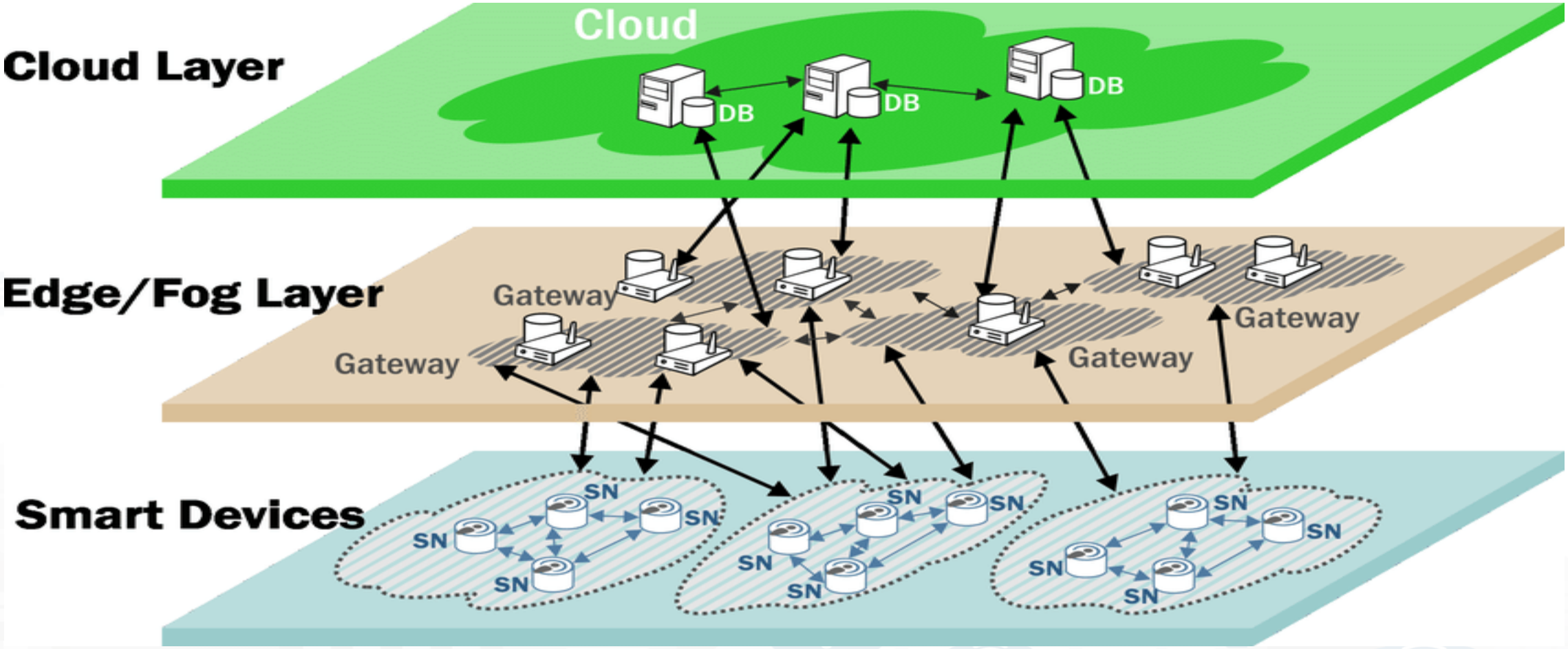


IOT Main Concept

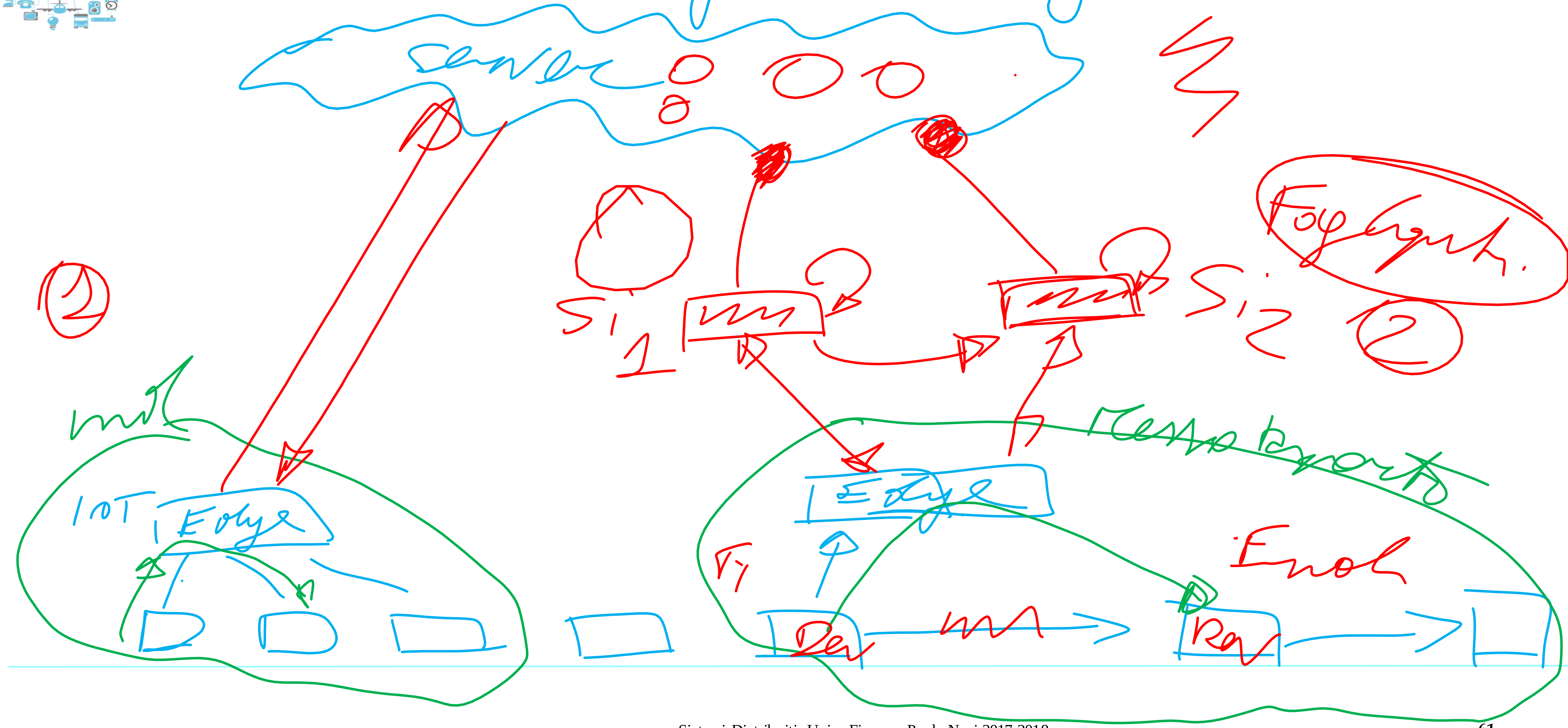
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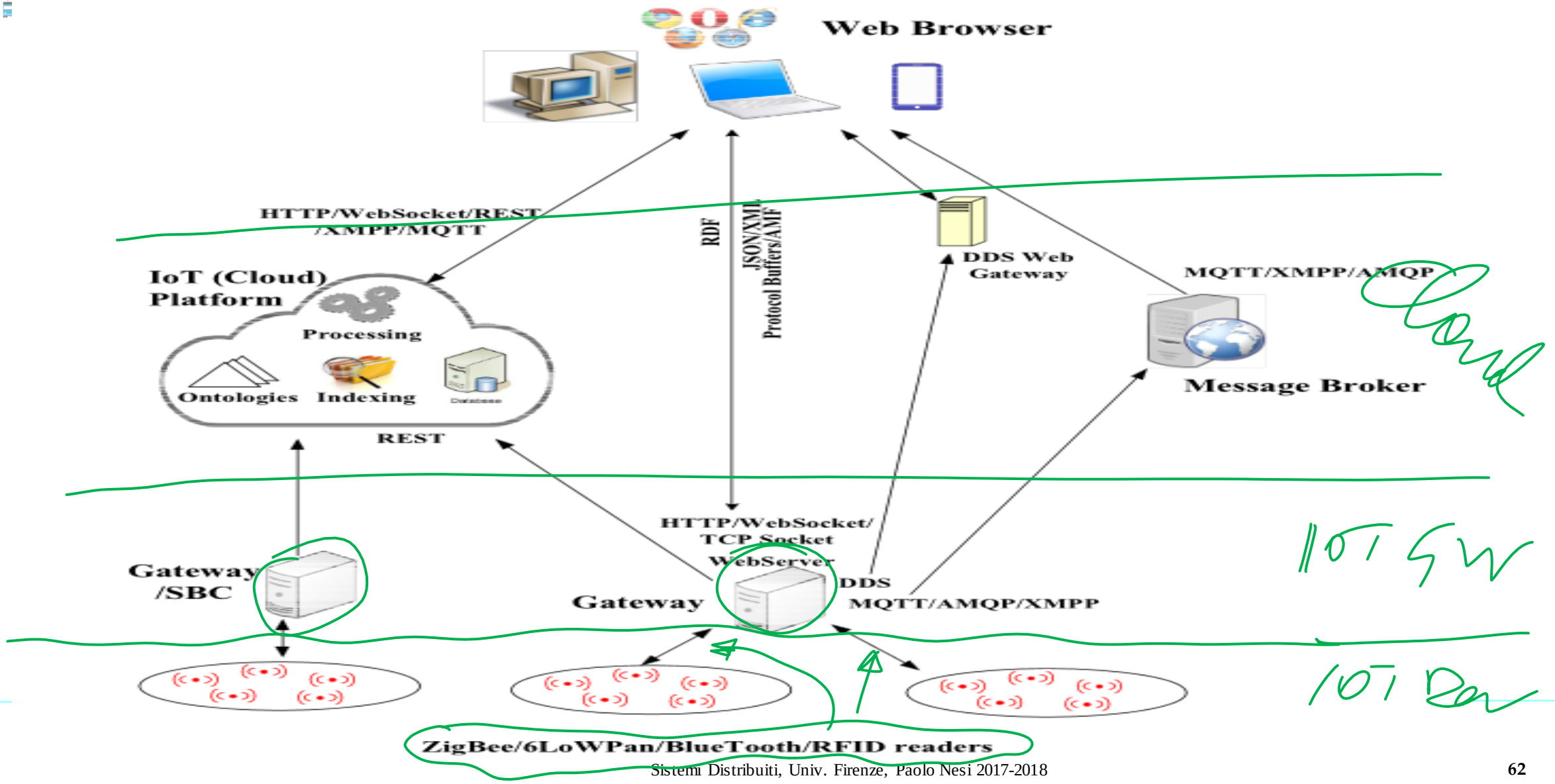
Cloud vs Fog/Edge Computing

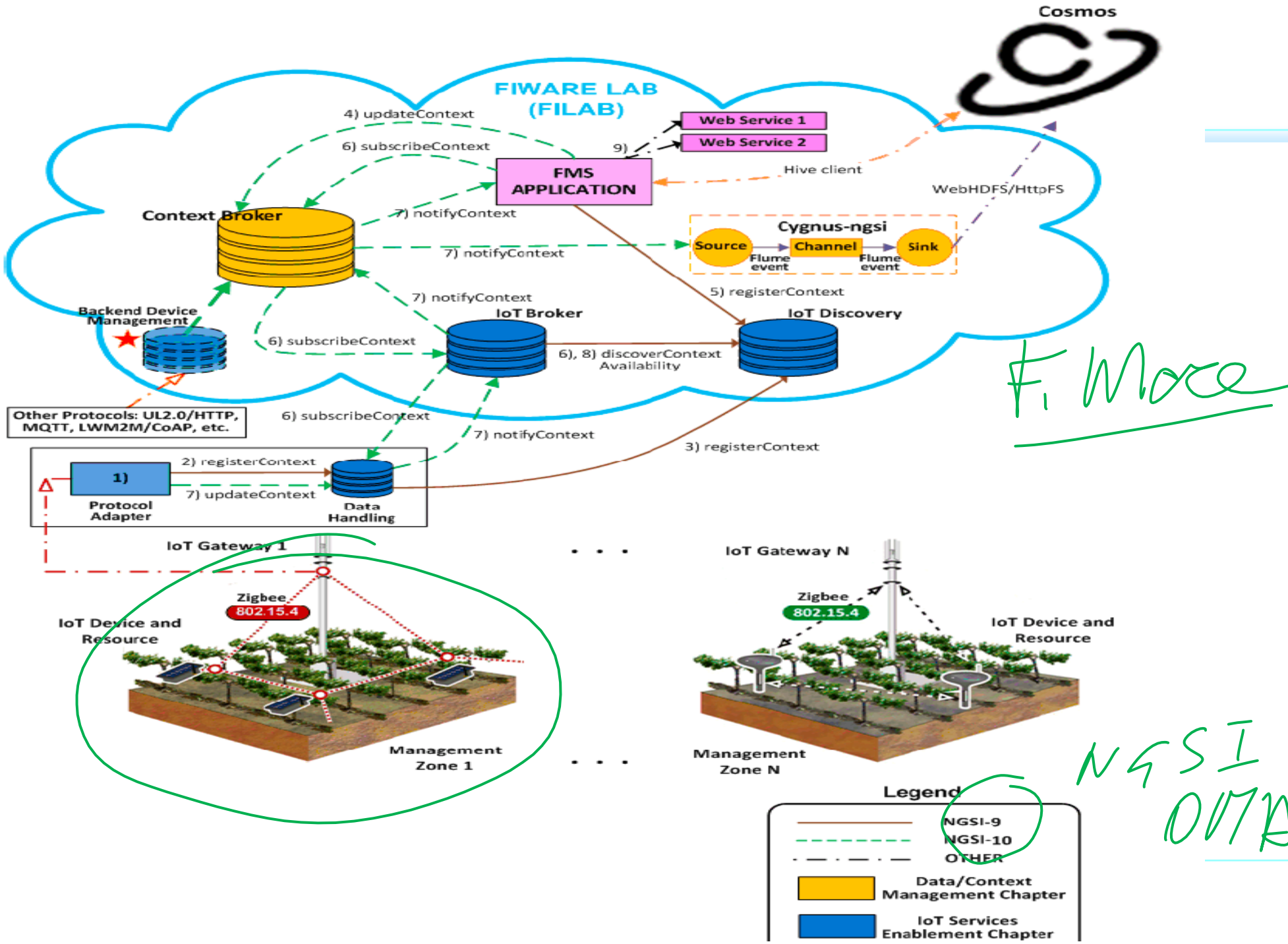


IOT edge vs Fog



Edge Computing, Fog Computing



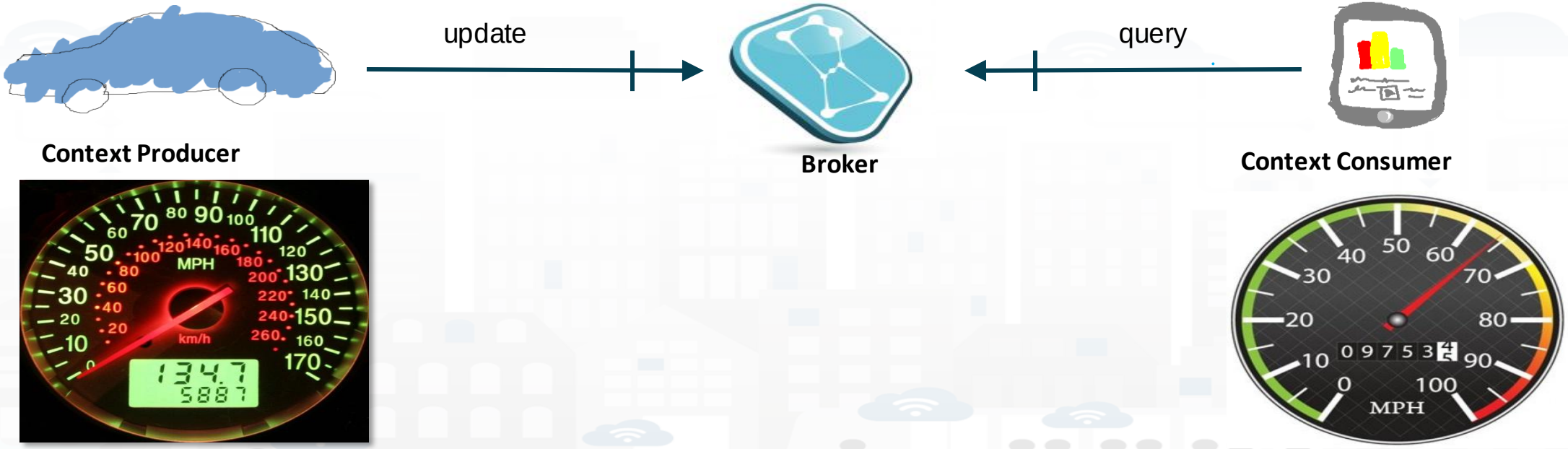


F. Mazzo

NGSI OMA

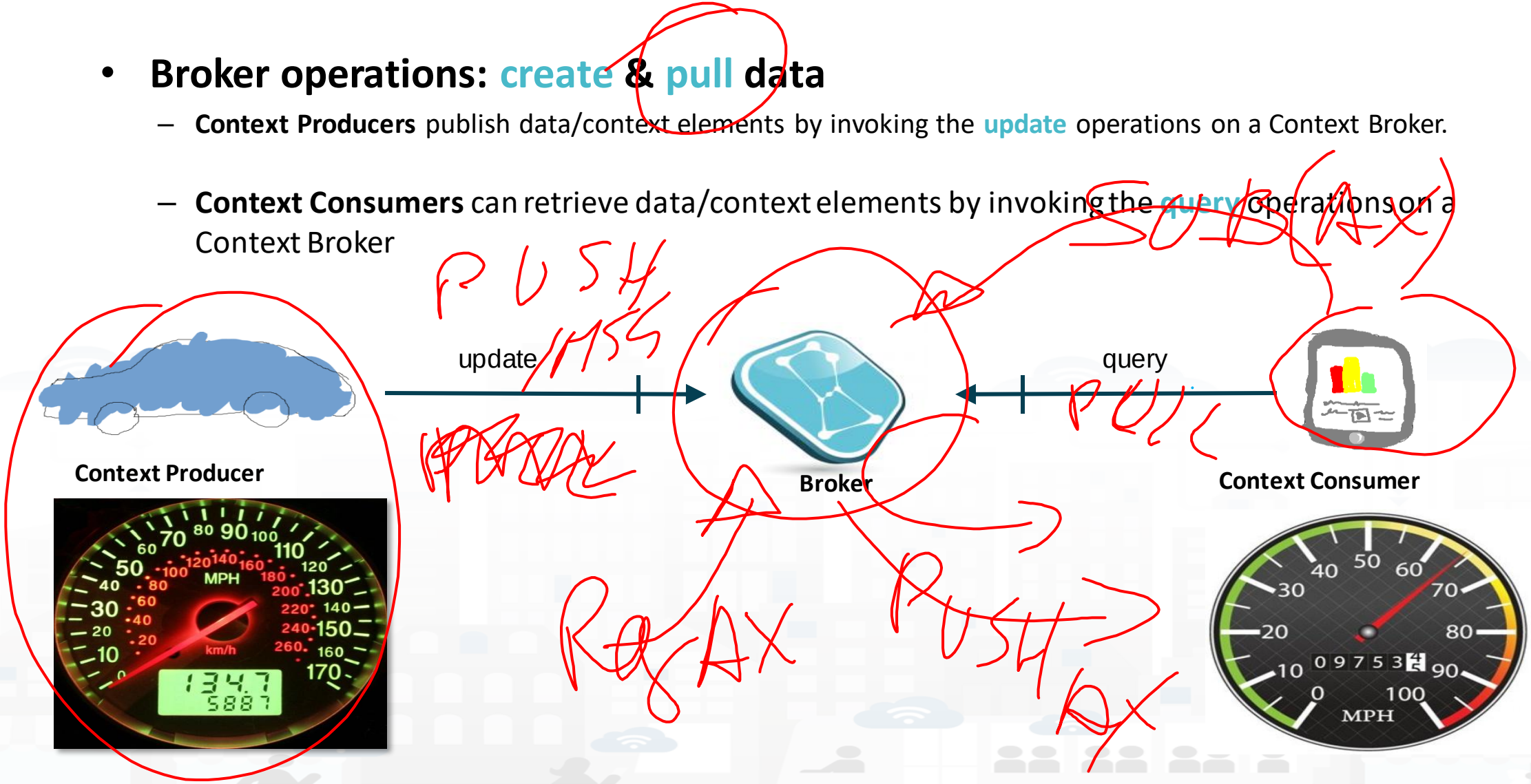
Broker

- **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

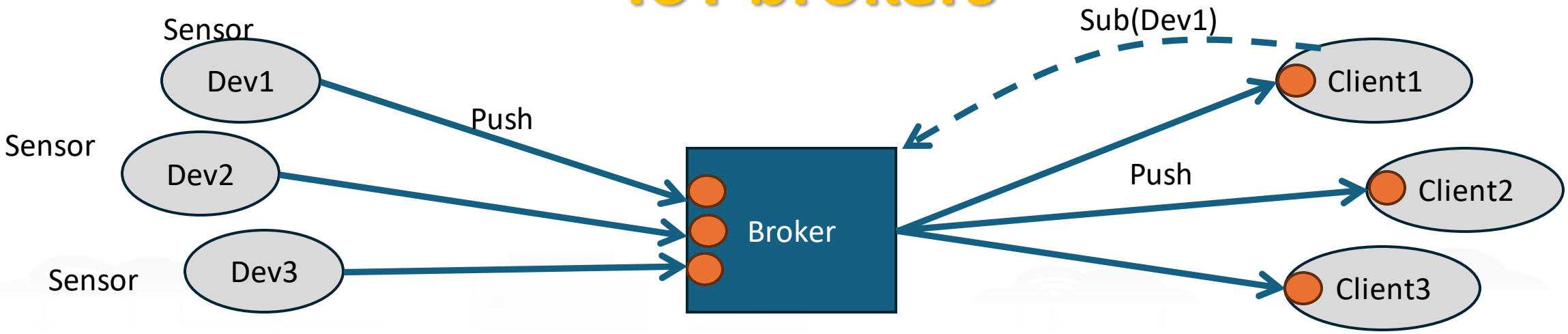


IOT Broker

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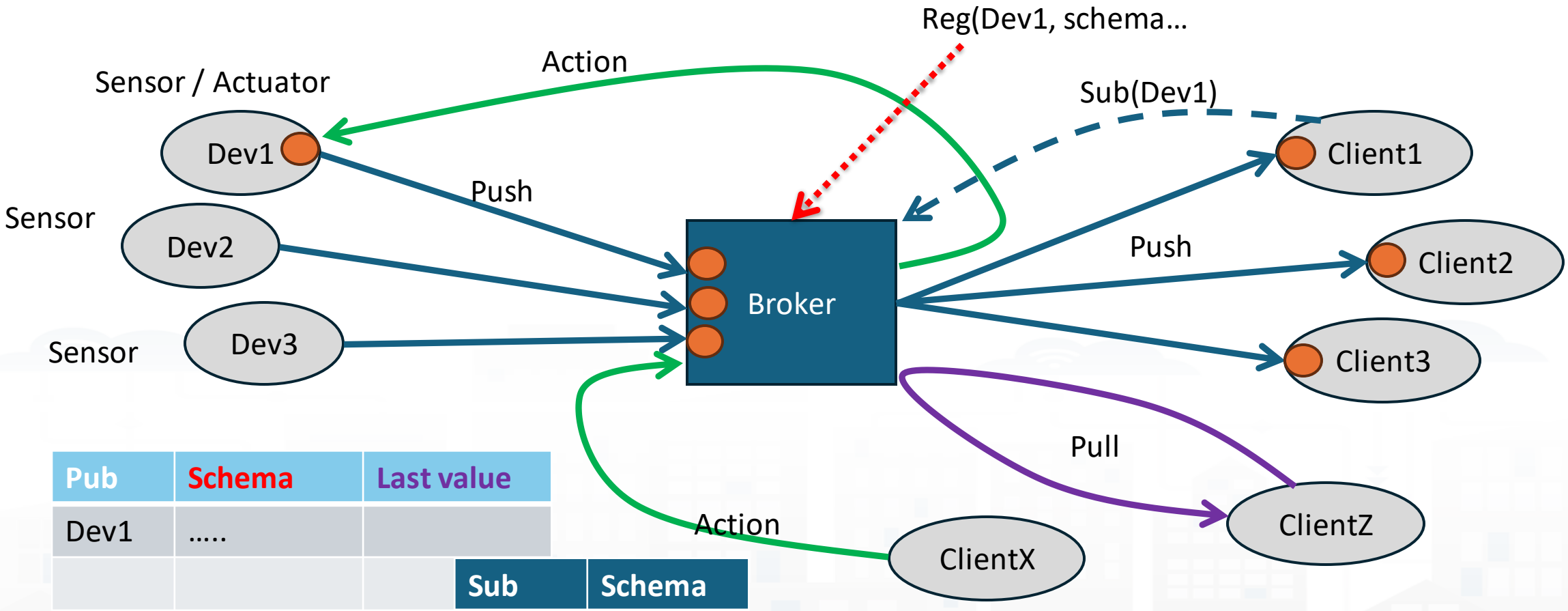


IoT brokers



Pub
Dev1

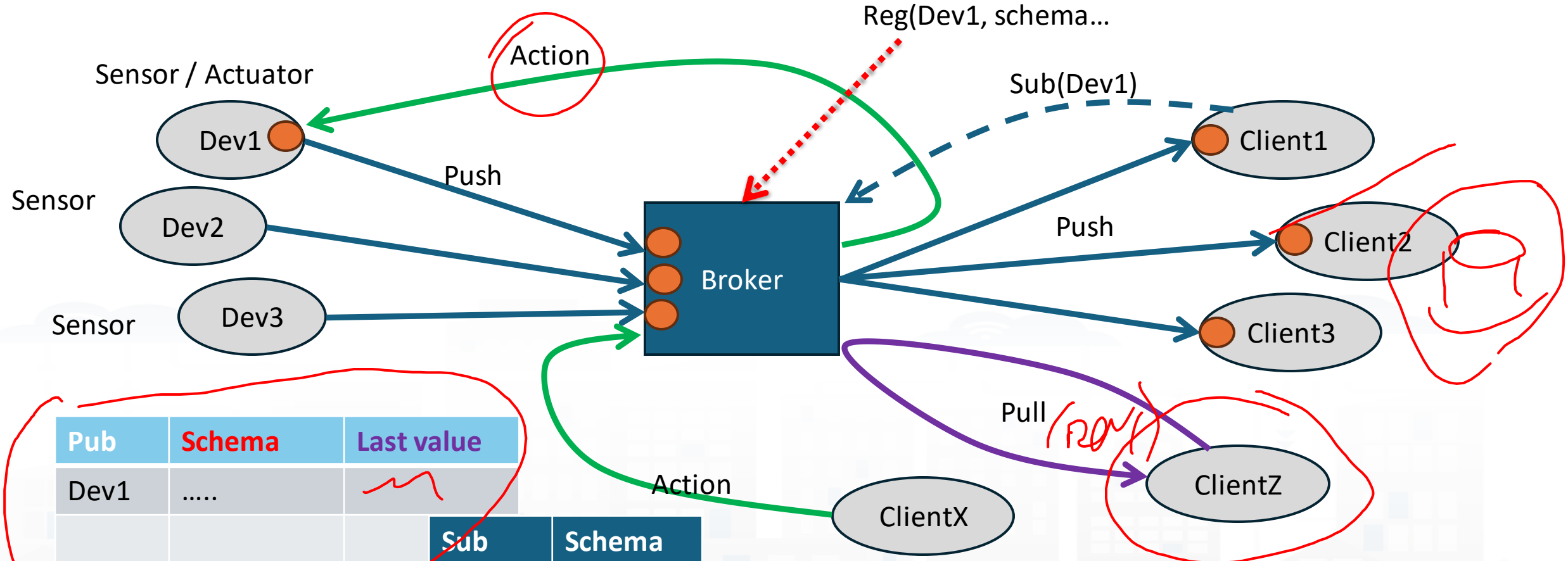
Sub	Schema
Client1	Dev1
Client1	Dev2



Pub	Schema	Last value
Dev1	…..	

Sub	Schema
Client1	Dev1
Client1	Dev2

IoT Context Brokers

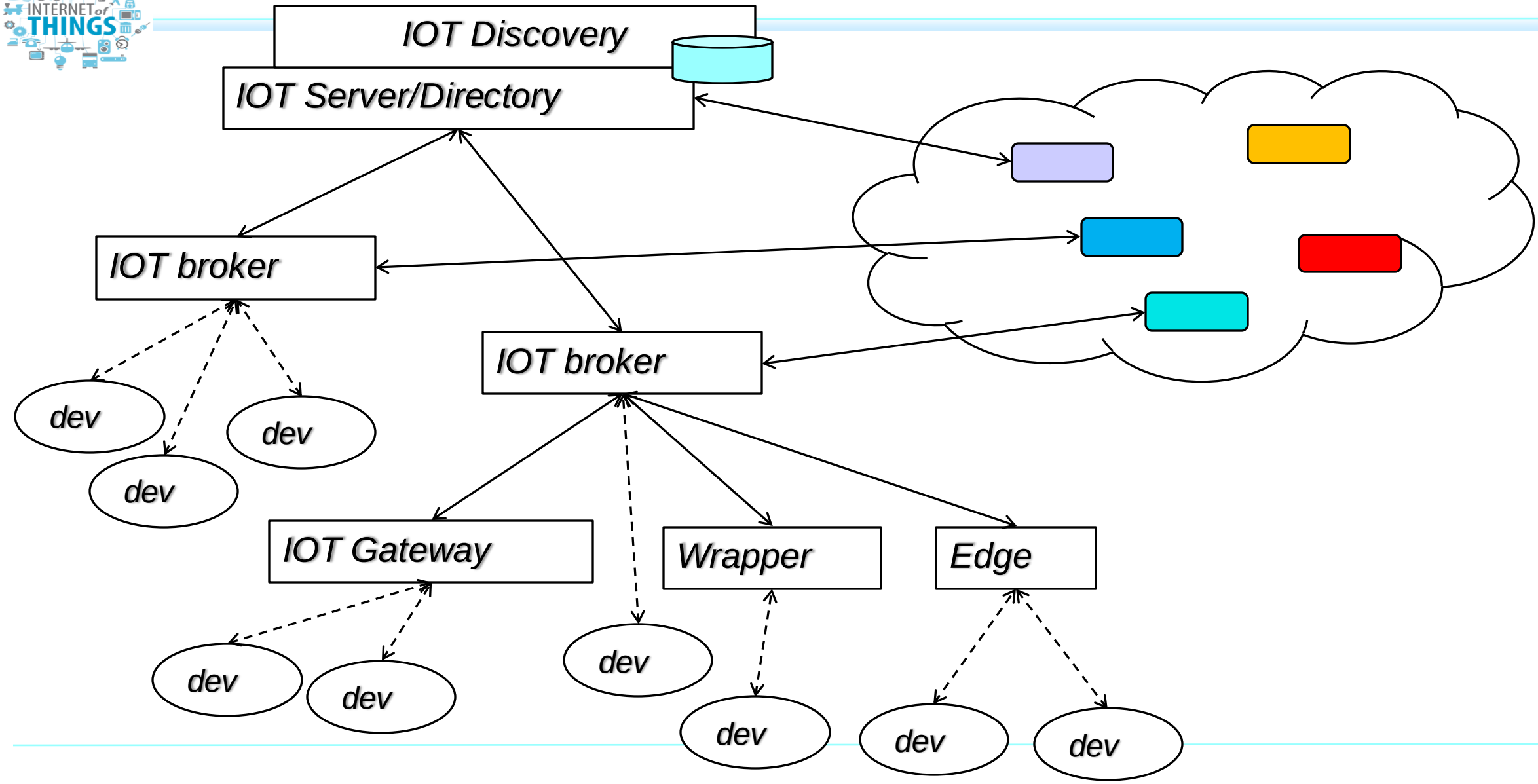


Pub	Schema	Last value
Dev1	…..	

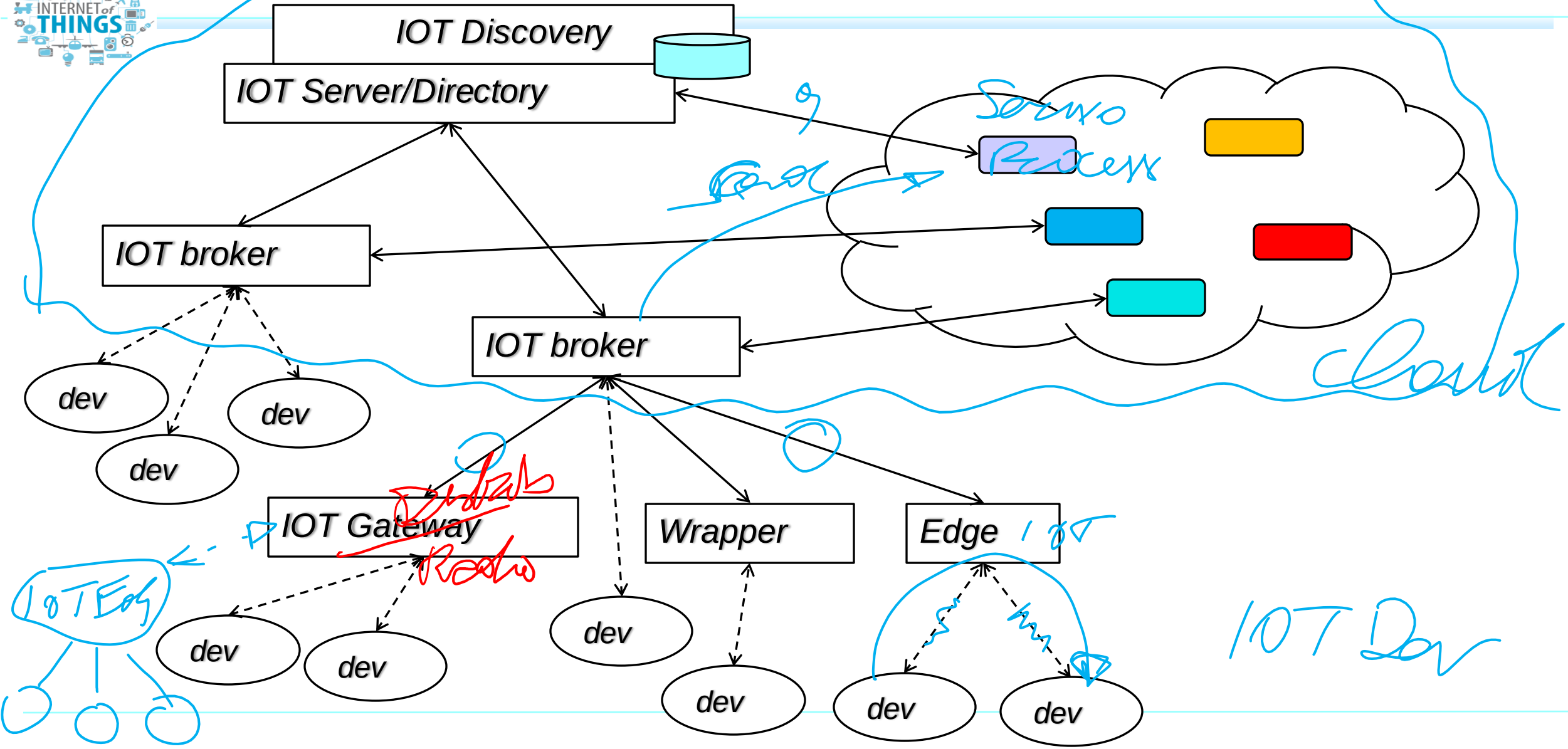
Sub	Schema
Client1	Dev1
Client1	Dev2

IoT Context Brokers

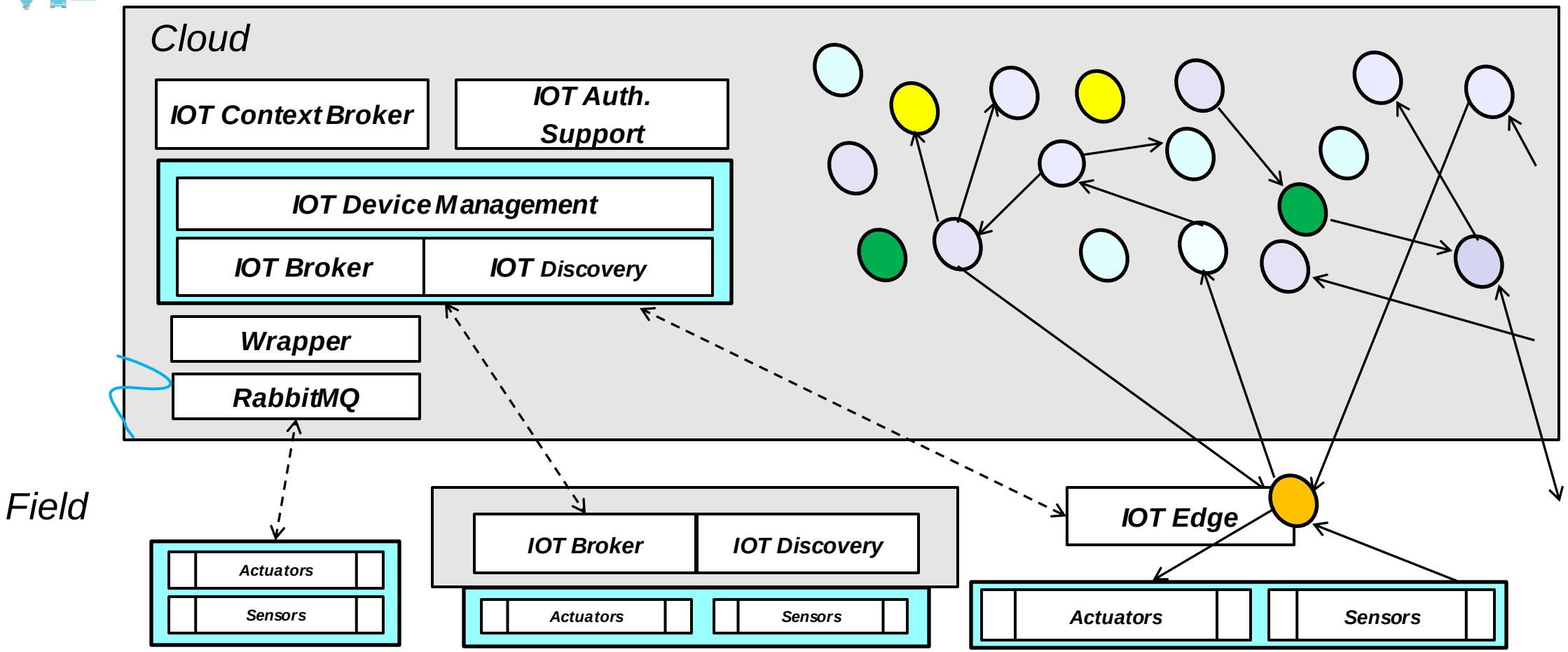
architettura



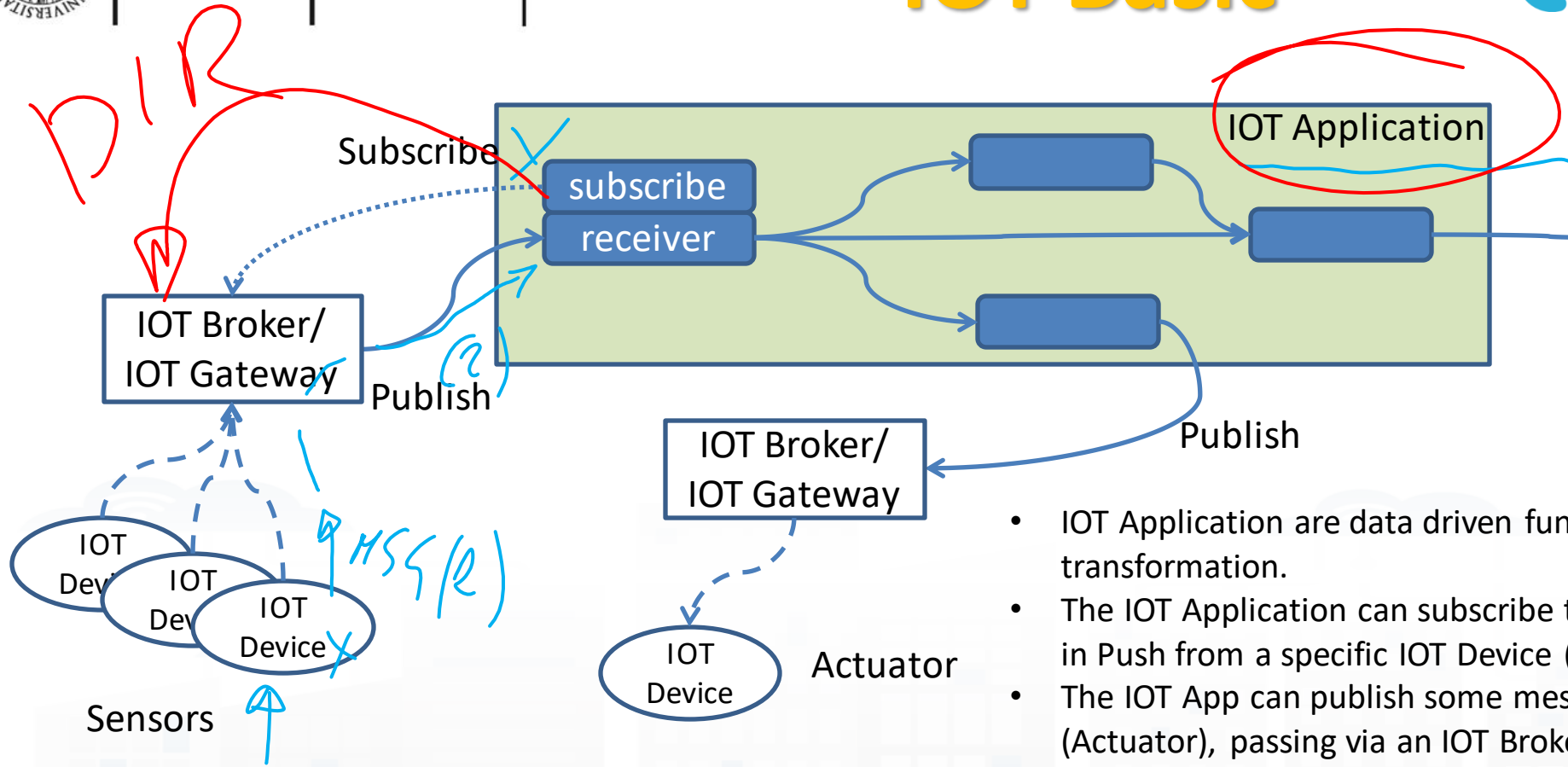
architettura



Conceptual architecture



IOT Basic

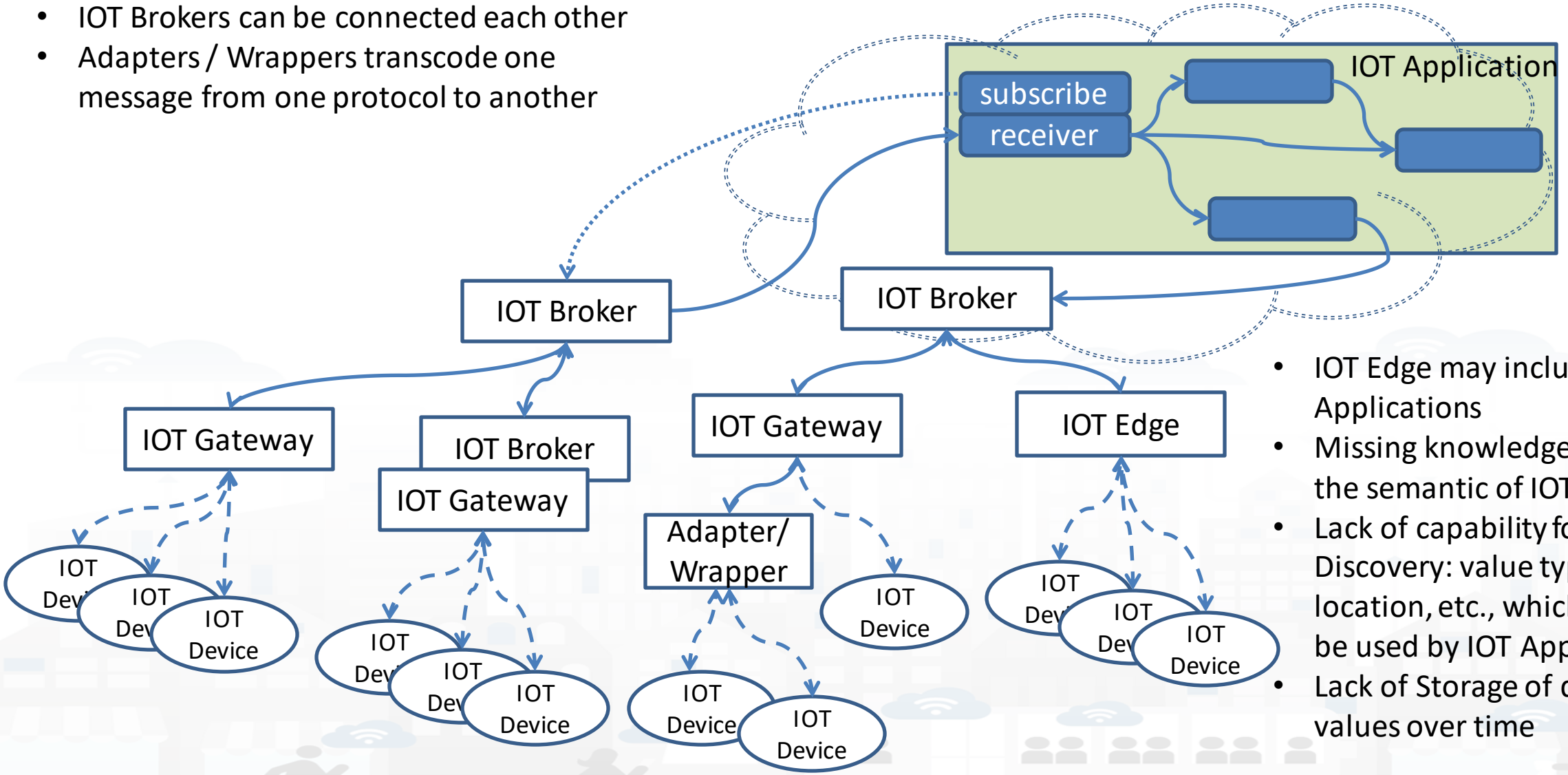


- Sensors are programmed to send data (i) periodically, or (ii) when a relevant change occurs in the sensor value, or (iii) when events occur (for example a change of status of something), etc.
- Actuator perform some action on the field: change of status, reset, turn on something, change setting value,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

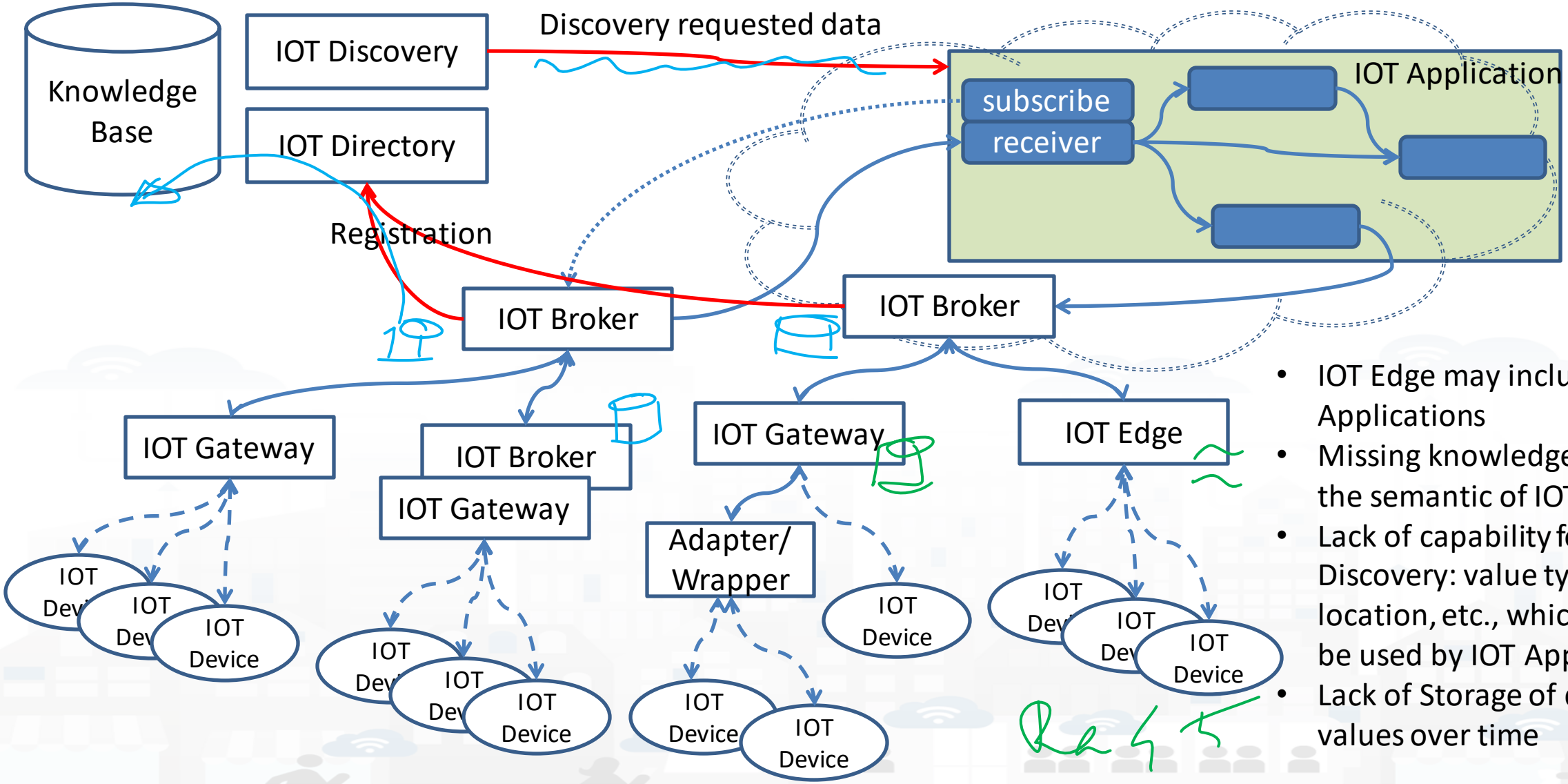
Definitions

- 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

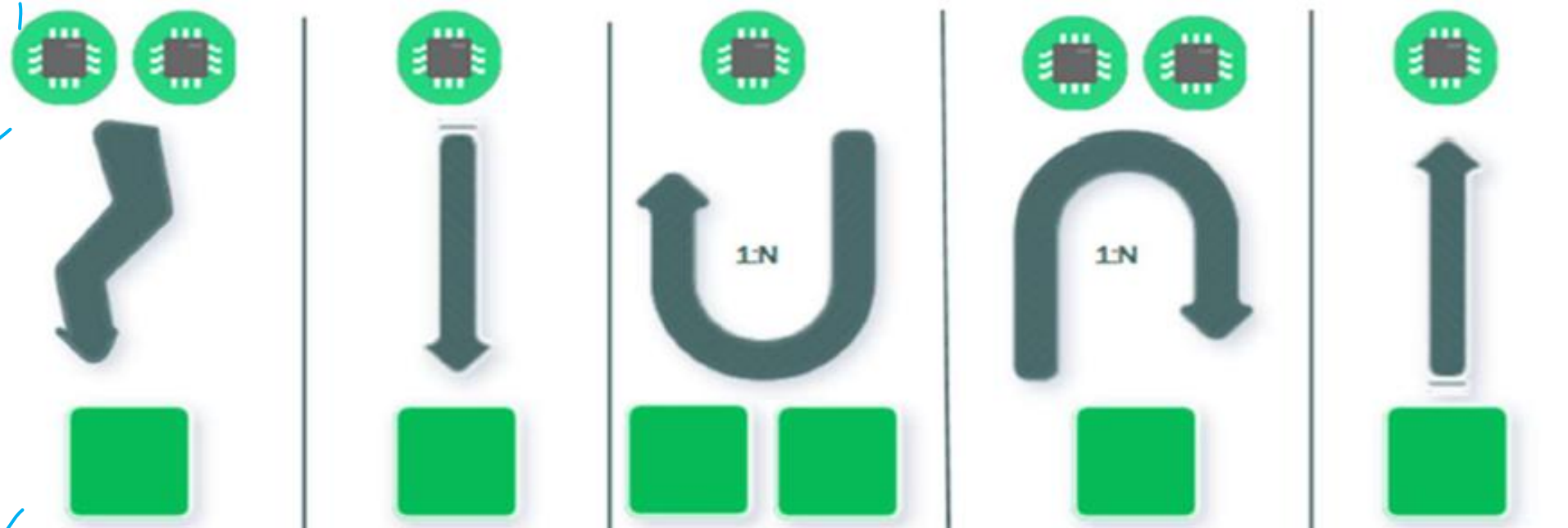
Definitions



- 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

IOT/IOE Protocols

Communication Patterns



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

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

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

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

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.

Registration

Push

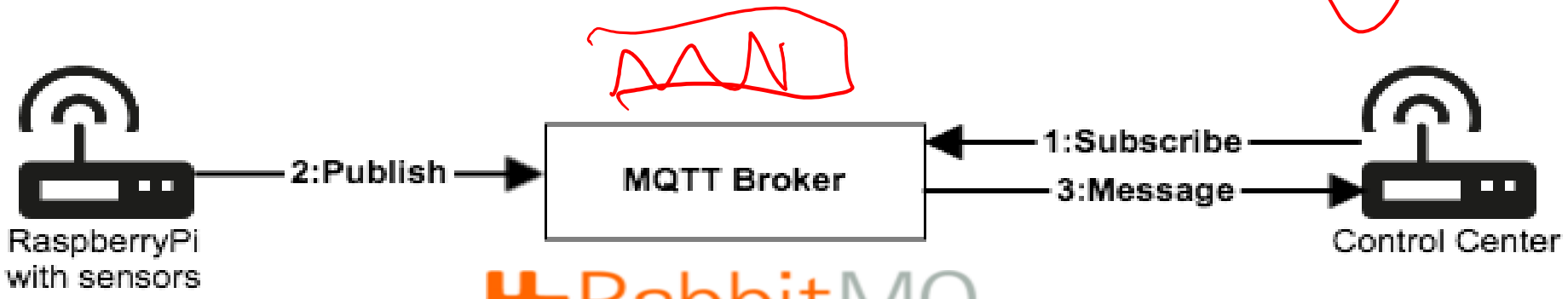
Bulk action

Note on Communication patterns

- Not all Communication Patterns are supported by all Protocols
- Protocols implement Patterns, + formats, + sequences, etc.
- They are referred at level of communications
  - IOT Device ← → IOT Gateway ←→IOT Broker
- IOT Protocols mostly used at level of IP are:
  - NGSI V1/2, MQTT, COAP, AMQP, OneM2M, WS, ModBUS,
- Radio protocols are: Lora, ZigBee, 3G, Wi-Fi, etc.
- Formats: JSON, Geo-JSON, Linked Data, XML, CSV,

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



RabbitMQ
Open Source Enterprise Messaging

IOT stack protocols

			Security	Management
Session		MQTT, SMQTT, CoRE, DDS, AMQP , XMPP, CoAP, …	TCG, Oath 2.0, SMACK, SASL, ISASecure, ace, DTLS, Dice, …	IEEE 1905, IEEE 1451, …
Network	Encapsulation	6LowPAN, 6TiSCH, 6Lo, Thread, …		
	Routing	RPL, CORPL, CARP, …		
Datalink		WiFi, Bluetooth Low Energy, Z-Wave, ZigBee Smart, DECT/ULE, 3G/LTE, NFC, Weightless, HomePlug GP, 802.11ah, 802.15.4e, G.9959, WirelessHART, DASH7, ANT+, LTE-A, LoRaWAN, …		

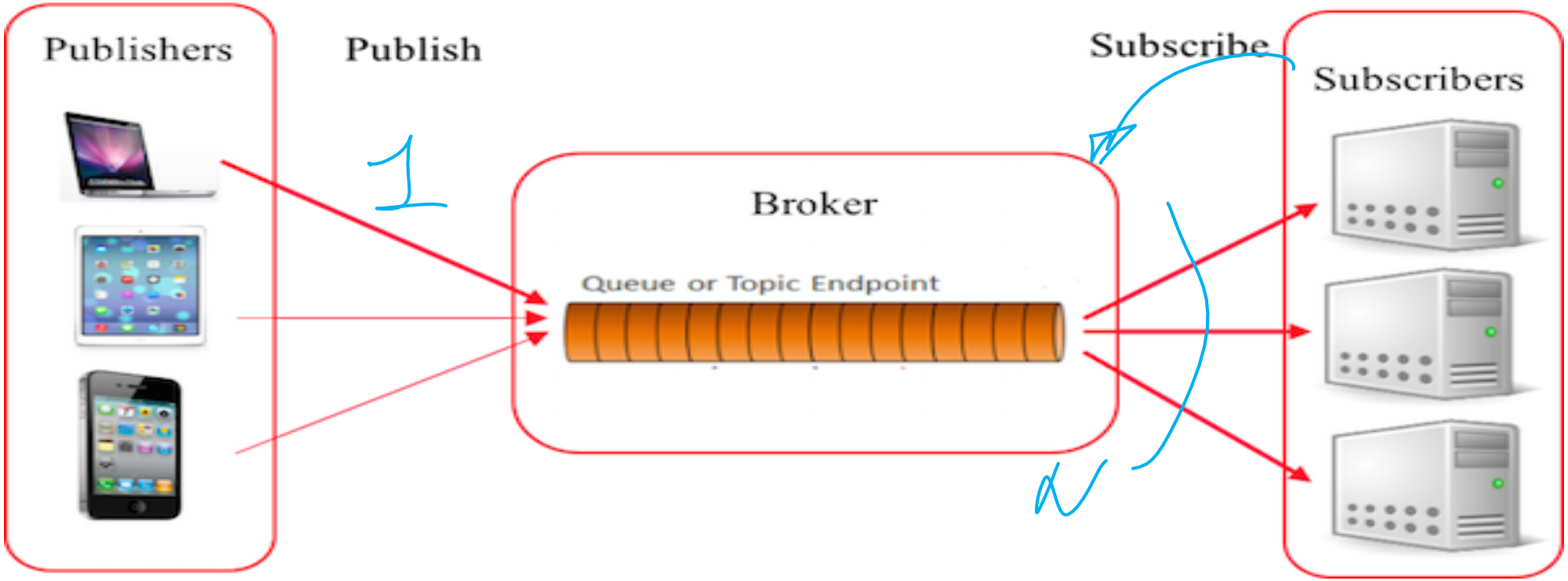
https://www.cse.wustl.edu/~jain/cse570-15/ftp/iot_prot/

Comparison high level IOT protocols

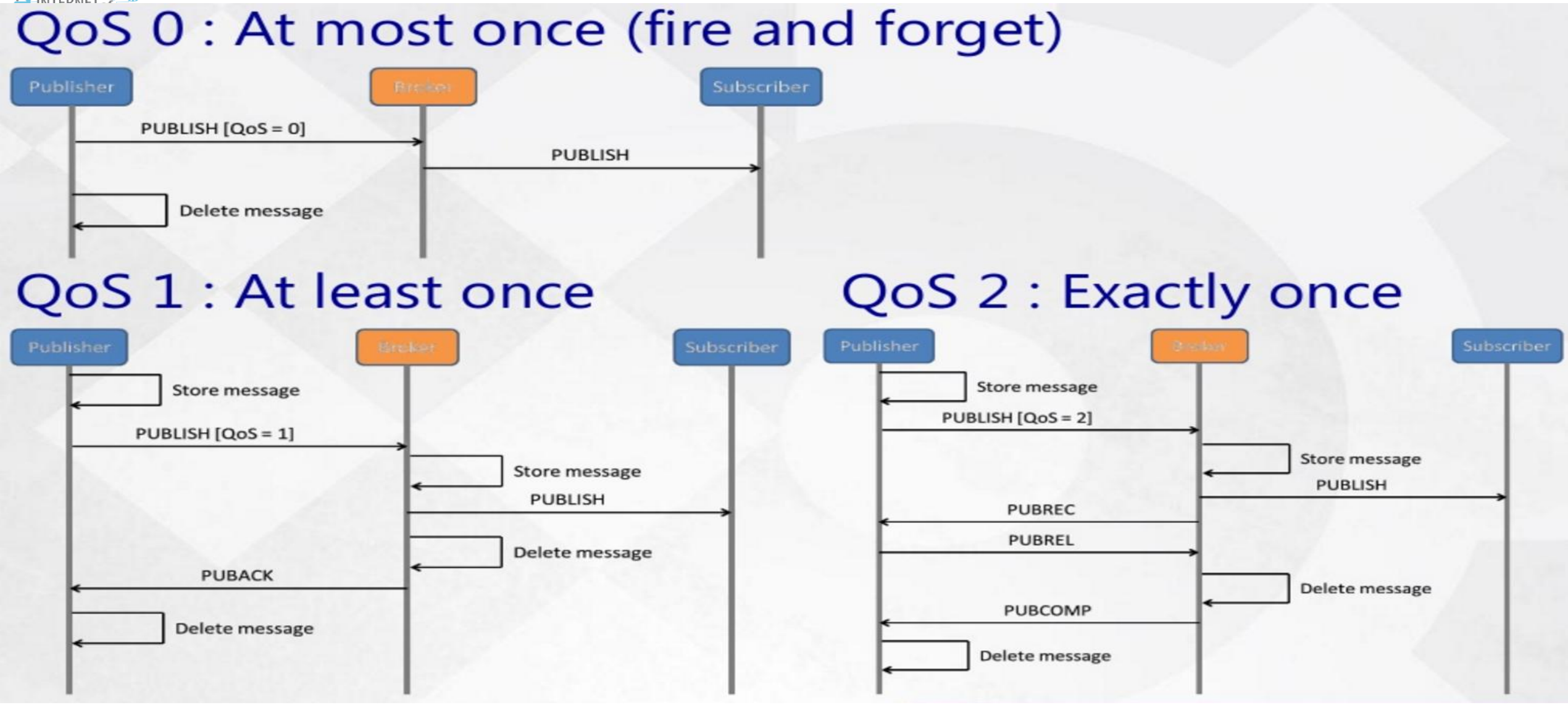
Protocols	UDP/TCP	Architecture	Security and QoS	Header Size (bytes)	Max Length(bytes)
MQTT	TCP	Pub/Sub	Both	2	5
AMQP	TCP	Pub/Sub	Both	8	-
CoAP	UDP	Req/Res	Both	4	20 (typical)
XMPP	TCP	Both	Security	-	-
DDS	TCP/UDP	Pub/Sub	QoS	-	-
NGSI	TCP/IP	Pub/Sub	QoS	7	—

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)

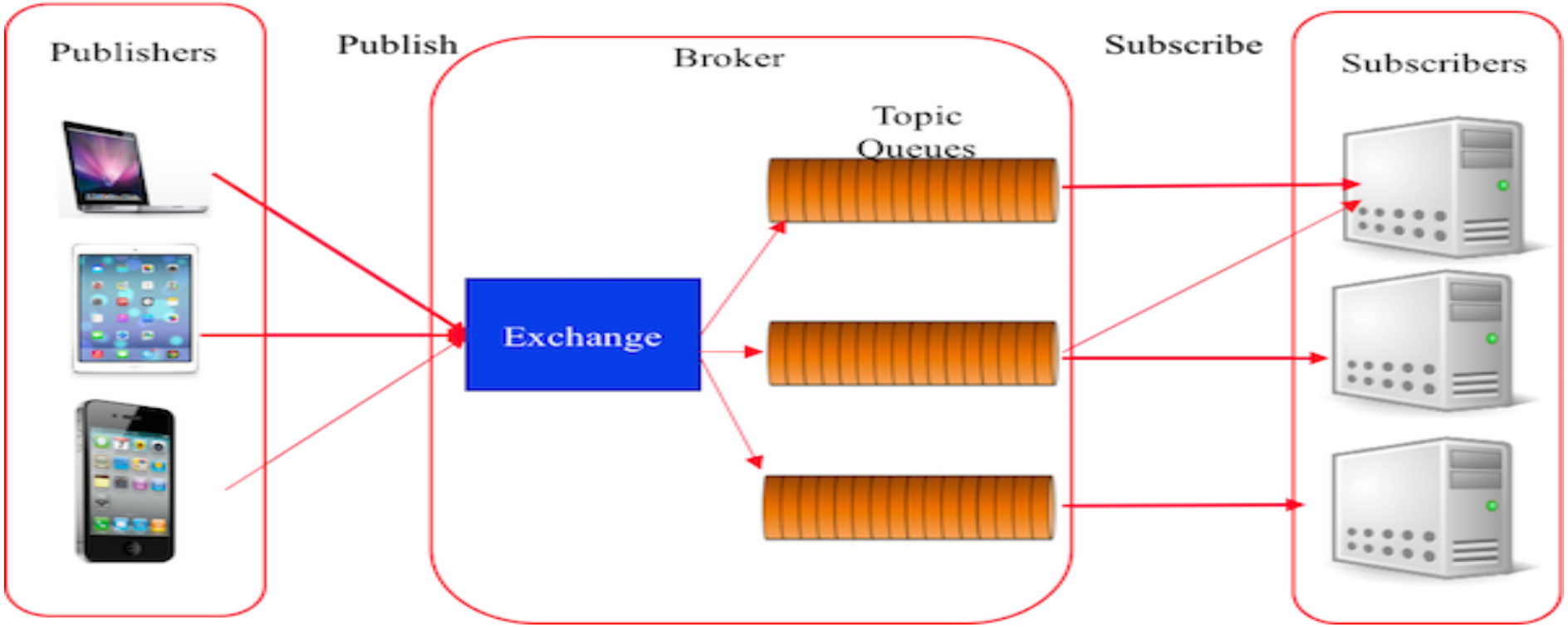


MQTT QoS


QoS 0 : At most once (fire and forget)
Publisher
Broker
Subscriber
PUBLISH [QoS = 0]
PUBLISH
Delete message
QoS 1 : At least once
Publisher
Broker
Subscriber
Store message
PUBLISH [QoS = 1]
Store message
PUBLISH
Delete message
PUBACK
Delete message
QoS 2 : Exactly once
Publisher
Broker
Subscriber
Store message
PUBLISH [QoS = 2]
Store message
PUBLISH
PUBREC
PUBREL
Delete message
PUBCOMP
Delete message

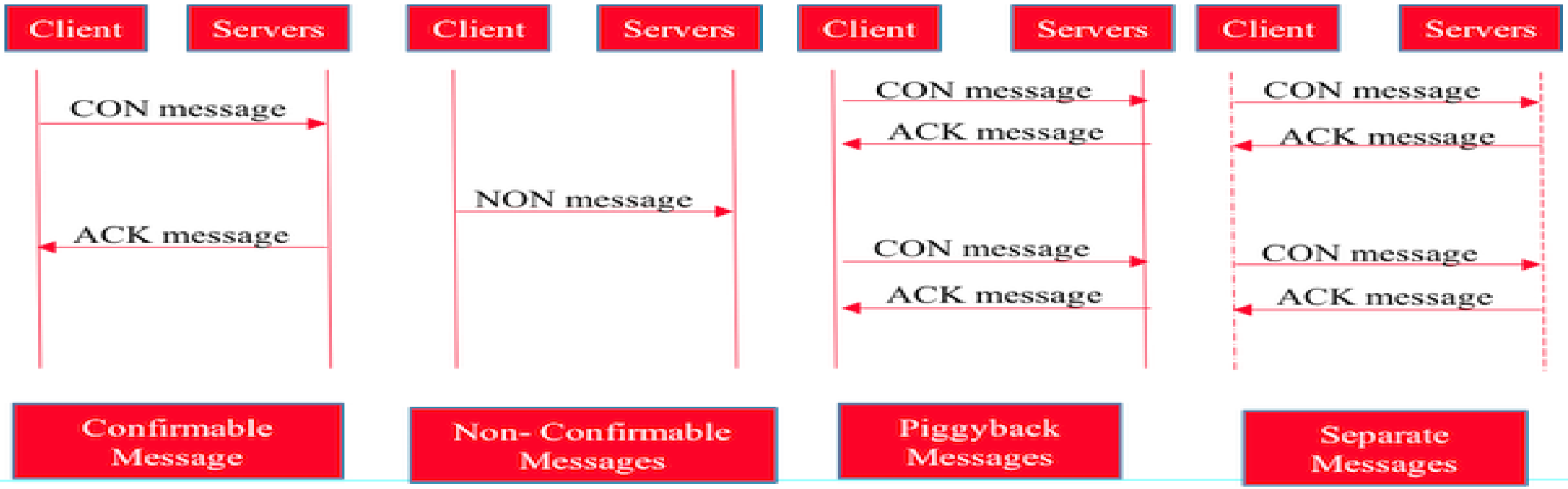
AMQP Advanced Message Queuing Protocol

- Over TCP, binary wire protocol
- Exchange decoupling



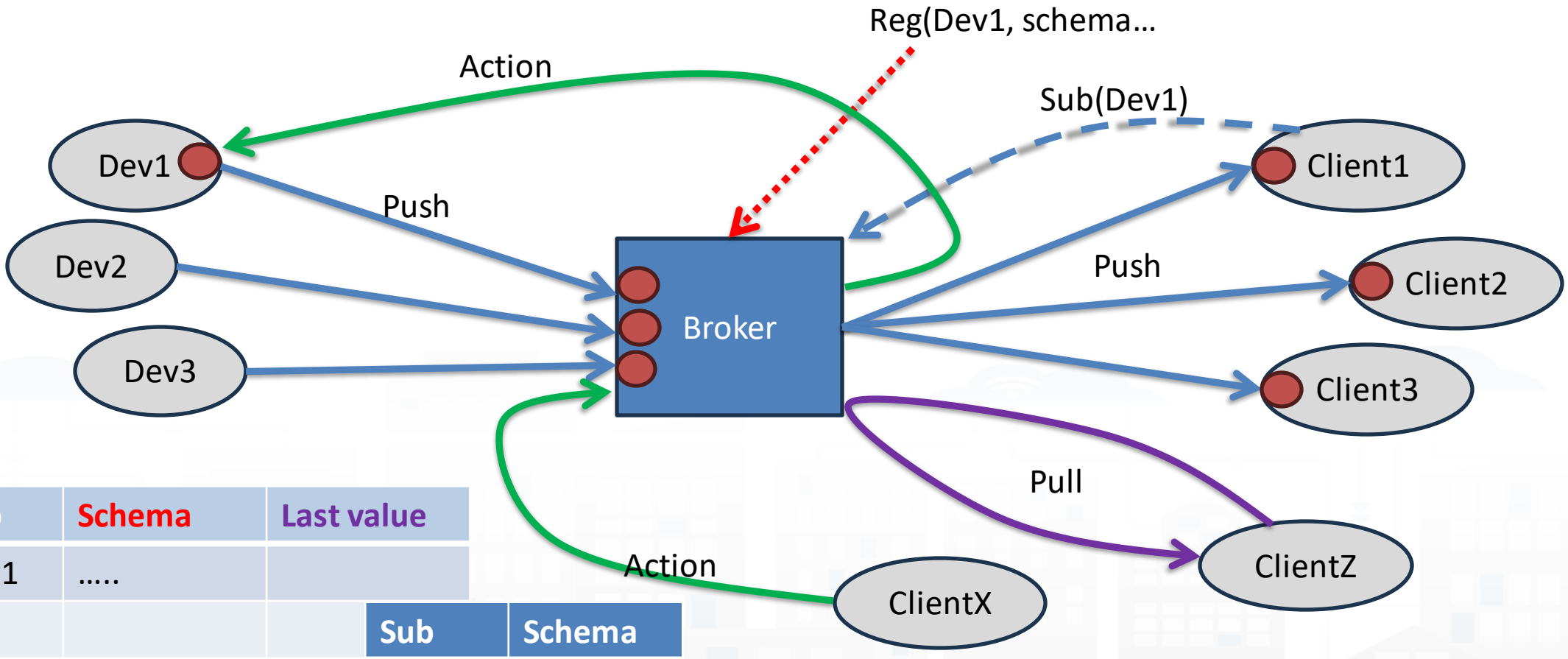
CoAP: Constrained Application Protocol

- OMA LWM2M over IETF CoAP (Internet Engineering Task Force)
- security obtained with DTLS, Datagram TLS
- HTTP like over UDP with fixed header, no TCP



Other protocols

- **STOMP**: Streaming Text Oriented Messaging Protocol
  - Similar to HTTP
- **XMPP**: Extensible Messaging and Presence Protocol
  - Based on XML, proposed by IETF
  - Over TCP, can use HTTP
- **WAMP**: Web Application Messaging Protocol
  - WebSocket protocol by IANA
  - Over level 6
- **SNMP** by IETF, level 7
  - Over UDP, or IP
  - Monitoring status of servers
- **SigFOX**
- **OneM2M** AIOTI
  - a strategic enabler for IoT applications and companies developing IoT solutions



Pub	Schema	Last value
Dev1	…..	

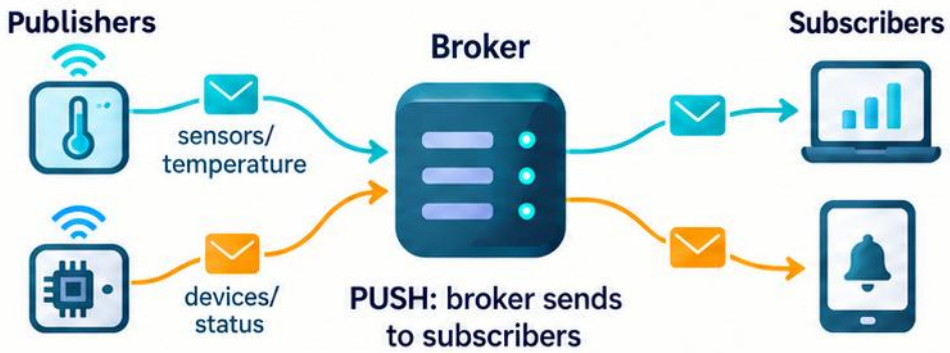
Sub	Schema
Client1	Dev1
Client1	Dev2

MQTT broker vs. Apache Kafka

Kafka producers PUSH; Kafka consumers PULL

MQTT broker

Lightweight publish / subscribe

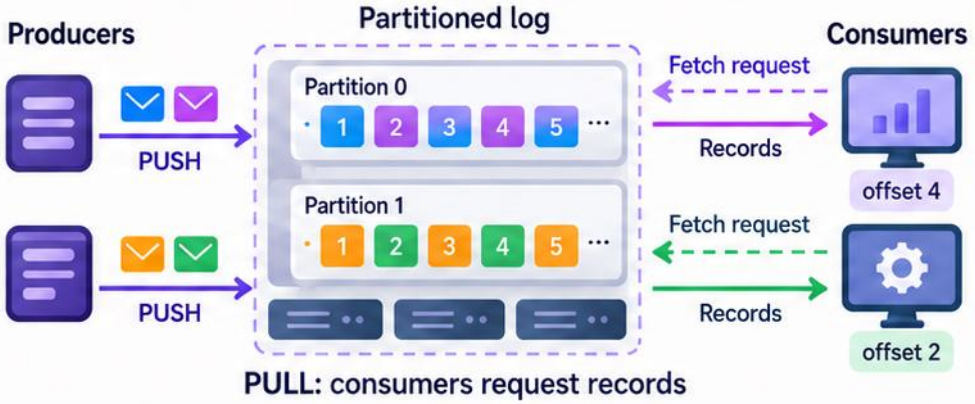


- Routes messages by topic
- Retained message: latest value per topic
- Persistent sessions can buffer offline delivery

IoT telemetry and device commands

Apache Kafka

Distributed event streaming



- Durable history with configured retention
- Consumers track independent offsets
- Replay retained events; order per partition

Event pipelines, analytics and stream processing

MQTT is a protocol; Kafka is a platform. Both use brokers and support publish / subscribe.

Simplified comparison. MQTT storage and clustering depend on the broker implementation.

Aspect	FIWARE Orion Context Broker	Apache Kafka
Main purpose	Manage the current state/context of entities	Transport and retain streams of events
Mental model	“What is the current state of this thing?”	“What events happened, and in what order?”
Data model	Entities + attributes, via NGSI	Records/events in topics
Typical example	Vehicle123.speed = 52 km/h	Vehicle123 speed changed to 52
Query current state	Yes, directly	Not its primary abstraction
Historical replay	Not the main purpose	Core feature
Subscriptions	Yes, notify when context changes	Yes, consumers continuously consume topics
Persistence	Orion focuses on current context; historical persistence normally uses additional components	Kafka durably retains events according to retention policy
Interface	Mainly HTTP REST / NGSIv2	Kafka producer/consumer protocol and client APIs
Scaling model	Context broker/API service	Distributed partitioned event log
Typical use cases	Smart cities, IoT digital twins, context-aware applications	Event-driven systems, pipelines, telemetry, logs, stream processing
Protocol model	No at most one	Yes at most one

Comparison of lowlevel IOT prot.

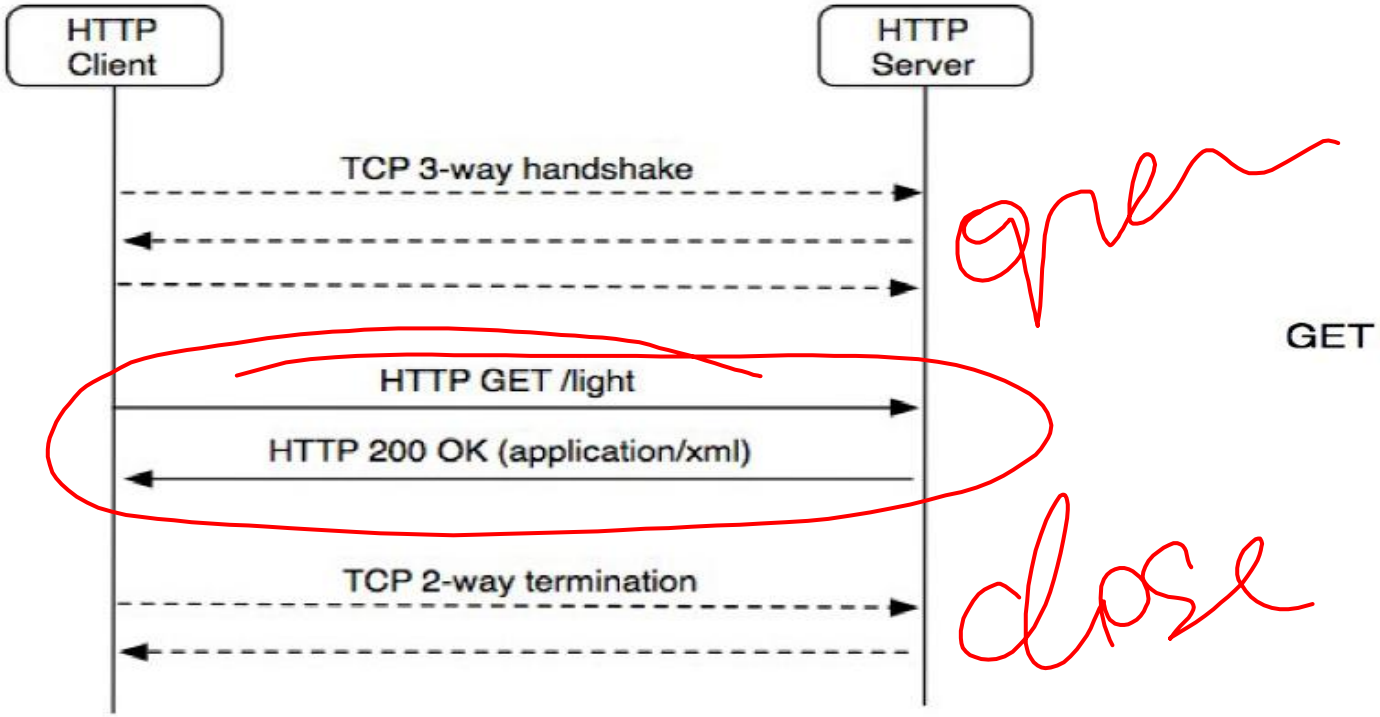
Protocolli IoT	Standard	Frequenza	Range	Data Rates
Bluetooth	Bluetooth 4.2	2.4GHz (ISM)	50-150m (Smart/BLE)	1Mbps (Smart/BLE)
ZigBee	ZigBee 3.0 based on IEEE802.15.4	2.4GHz	10-100m	250kbps
6LoWPAN	RFC6282	(adapted and used over a variety of other networking media including Bluetooth Smart (2.4GHz) or ZigBee or low-power RF (sub-1GHz)	Vedi protocollo di supporto	Vedi protocollo di supporto
WiFi	Based on 802.11n (most common usage in homes today)	2.4GHz and 5GHz bands	Approximately 50m	600 Mbps maximum, but 150-200Mbps is more typical, depending on channel frequency used and number of antennas (latest 802.11-ac standard should offer 500Mbps to 1Gbps)
Cellular	GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G)	900/1800/1900/2100MHz	35km max for GSM; 200km max for HSPA	(typical download): 35-170kps (GPRS), 120-384kbps (EDGE), 384Kbps-2Mbps (UMTS), 600kbps-10Mbps (HSPA), 3-10Mbps (LTE)
NFC	ISO/IEC 18000-3	13.56MHz (ISM)	10cm	100–420kbps
LoRaWAN	LoRaWAN	Various (europe, 868Mhz)	2-5km (urban environment), 15km (suburban environment)	0.3-50 kbps

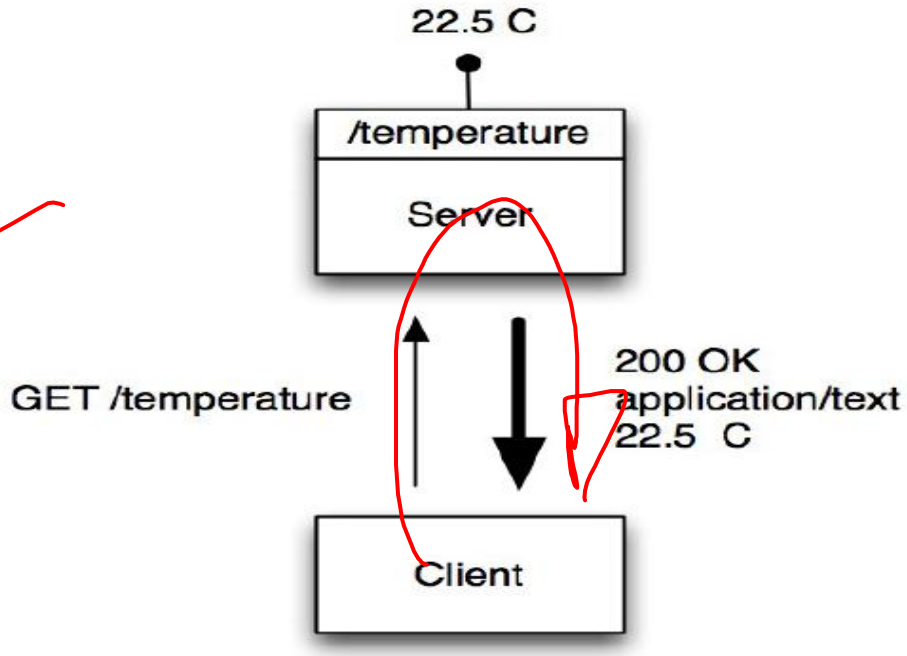
Main protocols



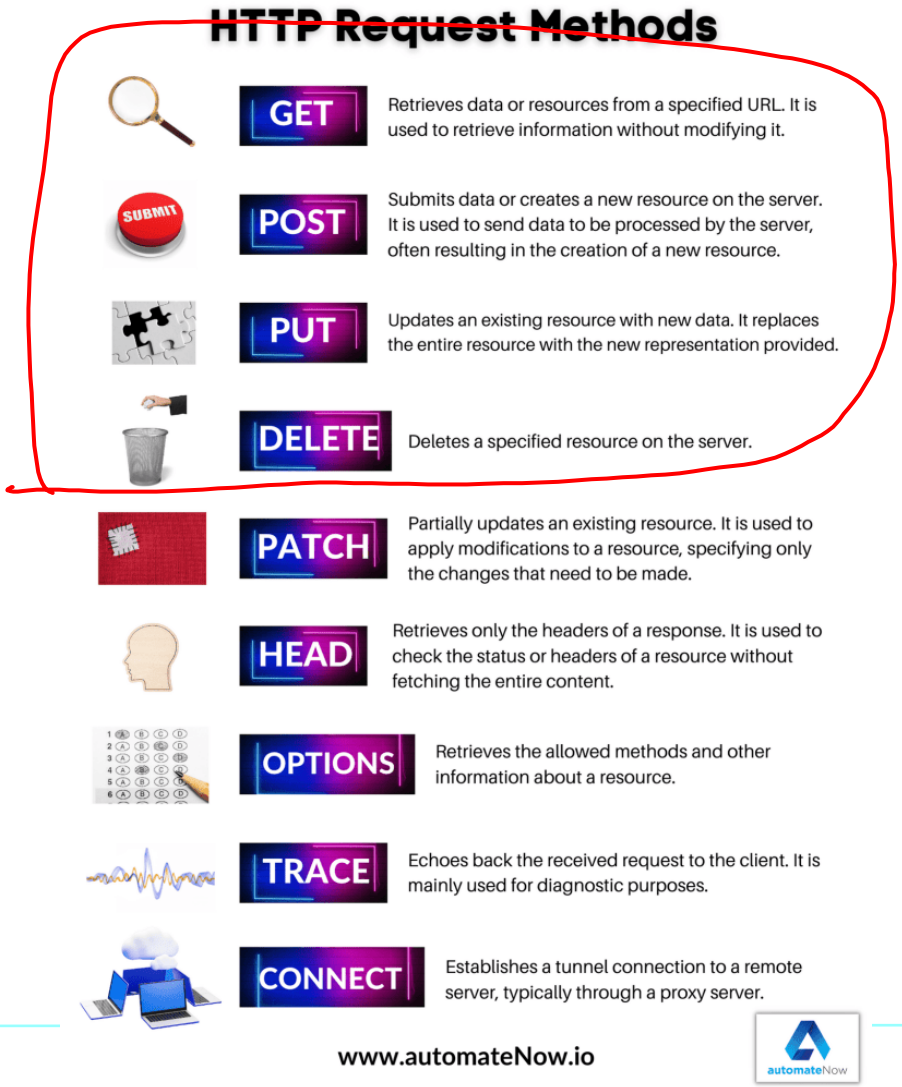
Protocol	How does It Work?	Use Cases
HTTP	TCP Connection, HTTP REQ, HTTP RESP	Web Browsing
HTTP/3 (QUIC)	UDP Connection	IoT, Virtual Reality
HTTPS	TCP Connection, public key, session key, encrypted data	Web Browsing
WebSocket	HTTP Upgrade, Full Duplex	Live Chat, Real-Time Data Transmission
TCP	SYN, SYN + ACK, ACK	Web Browsing, Email Protocols
UDP	REQUEST, RESPONSE	Video Conferencing
SMTP	sender, SMTP Server, receiver	Sending/Receiving Emails
FTP	Control Channel, Data Channel	Upload/Download Files

HTTP GET


HTTP Client
HTTP Server
TCP 3-way handshake
HTTP GET /light
HTTP 200 OK (application/xml)
TCP 2-way termination


22.5 C
/temperature
Server
GET /temperature
200 OK
application/text
22.5 C
Client

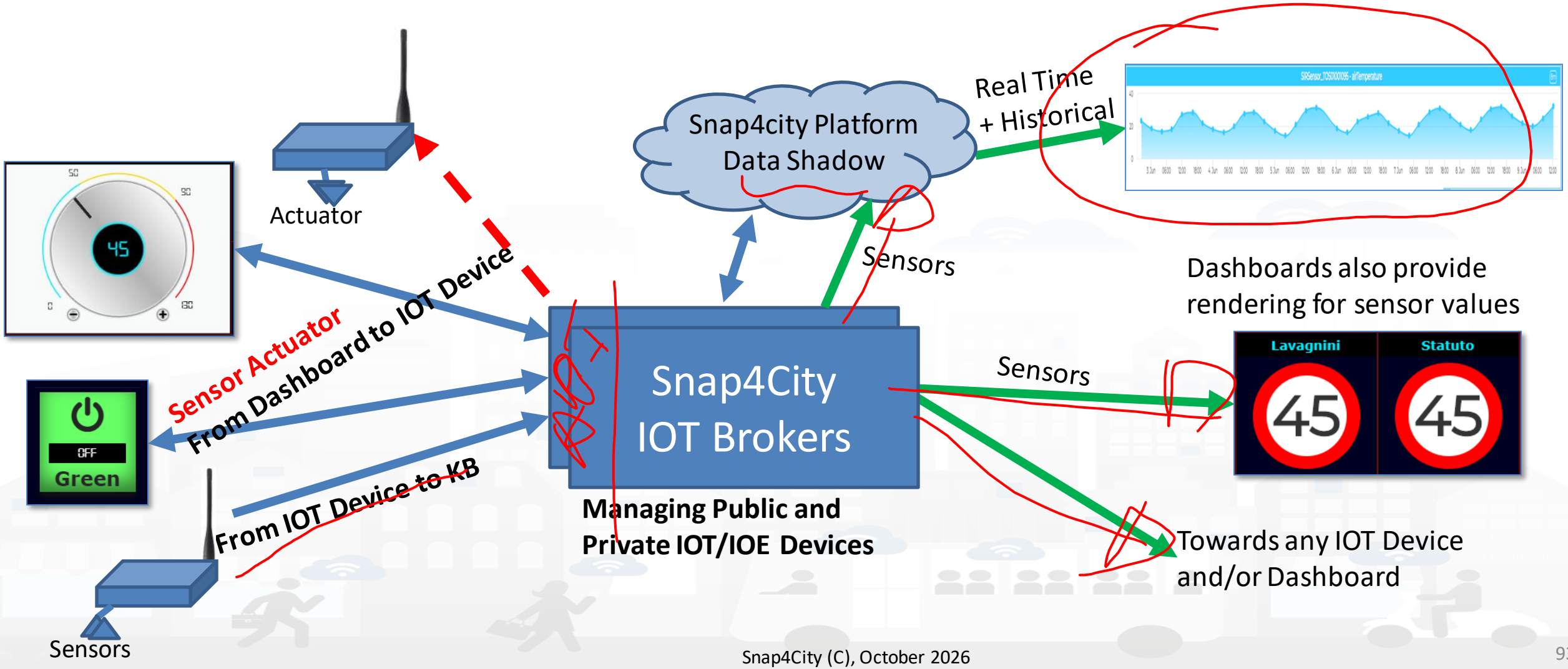
HTTP Method	Request has body	Response has body	Safe	Idempotent	Cachable
GET	NO	YES	YES	YES	YES
POST	YES	YES	NO	NO	YES
PUT	YES	YES	NO	YES	NO
DELETE	YES	YES	NO	YES	NO
TRACE	NO	YES	YES	YES	NO
OPTIONS	NO	YES	YES	YES	NO
CONNECT	NO	YES	NO	NO	NO
PATCH	YES	YES	NO	NO	NO



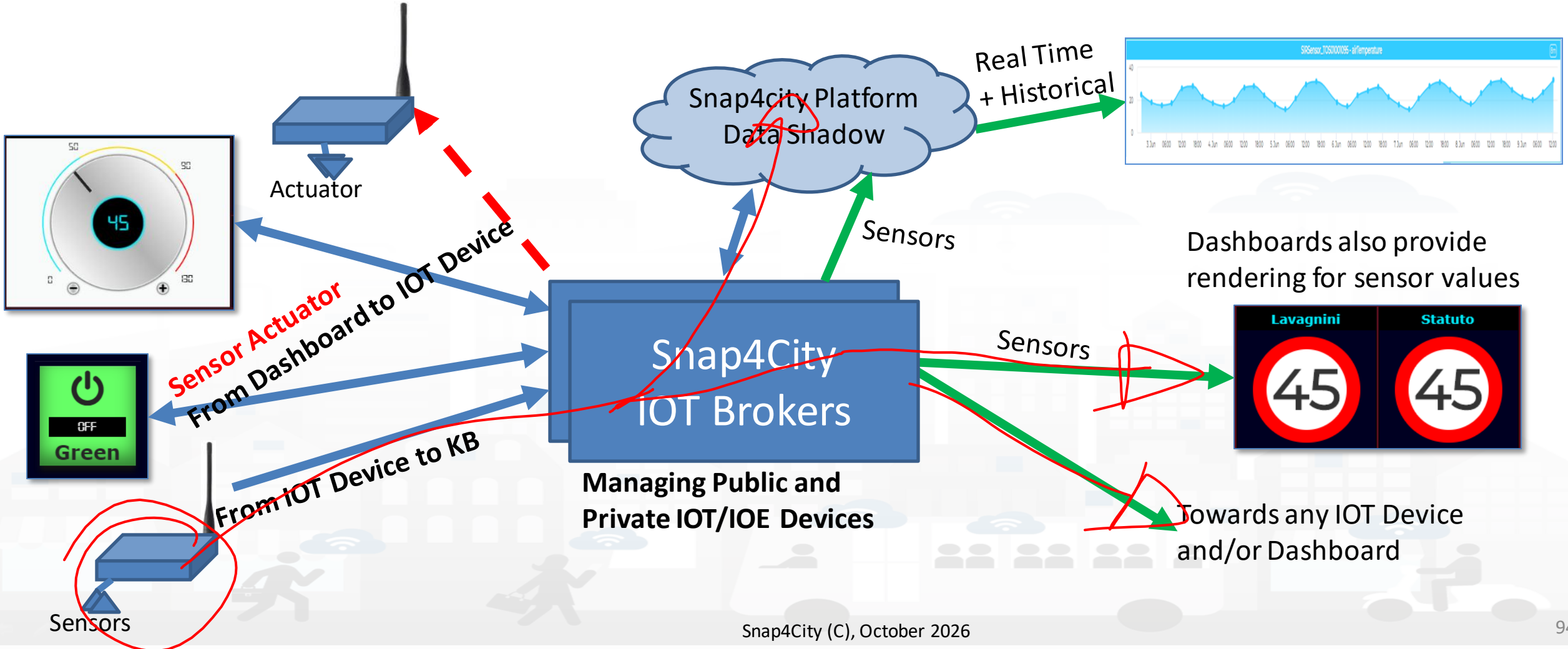
http GET vs POST

	GET	POST
BACK button/Reload	Harmless	Data will be re-submitted (the browser should alert the user that the data are about to be re-submitted)
Bookmarked	Can be bookmarked	Cannot be bookmarked
Cached	Can be cached	Not cached
Encoding type	application/x-www-form-urlencoded	application/x-www-form-urlencoded or multipart/form-data. Use multipart encoding for binary data
History	Parameters remain in browser history	Parameters are not saved in browser history
Restrictions on data length	Yes, when sending data, the GET method adds the data to the URL; and the length of a URL is limited (maximum URL length is 2048 characters)	No restrictions
Restrictions on data type	Only ASCII characters allowed	No restrictions. Binary data is also allowed
Security	GET is less secure compared to POST because data sent is part of the URL Never use GET when sending passwords or other sensitive information!	POST is a little safer than GET because the parameters are not stored in browser history or in web server logs
Visibility	Data is visible to everyone in the URL	Data is not displayed in the URL

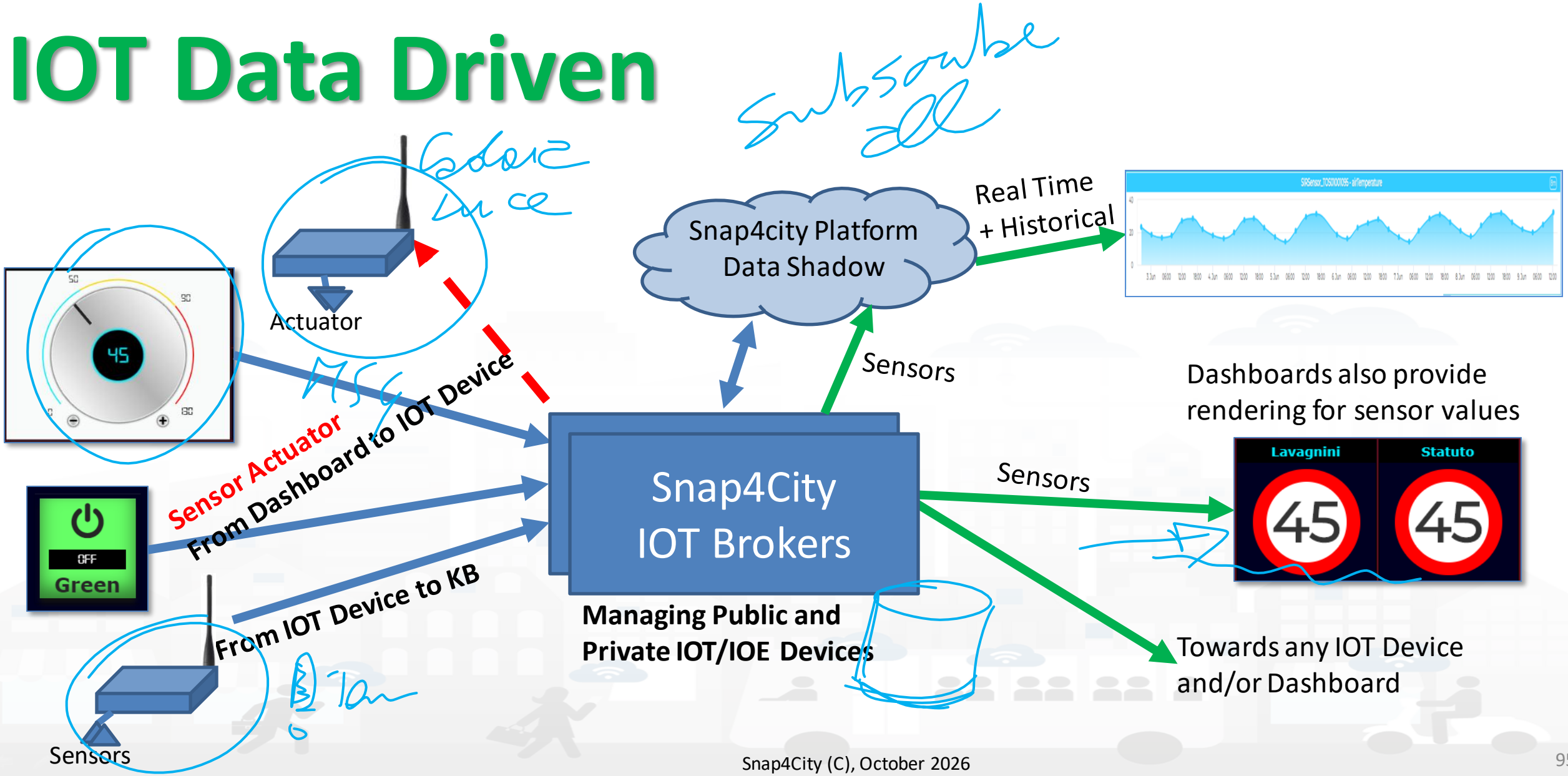
IOT Data Driven



IOT Data Driven



IOT Data Driven



IOT Architectures Comparison



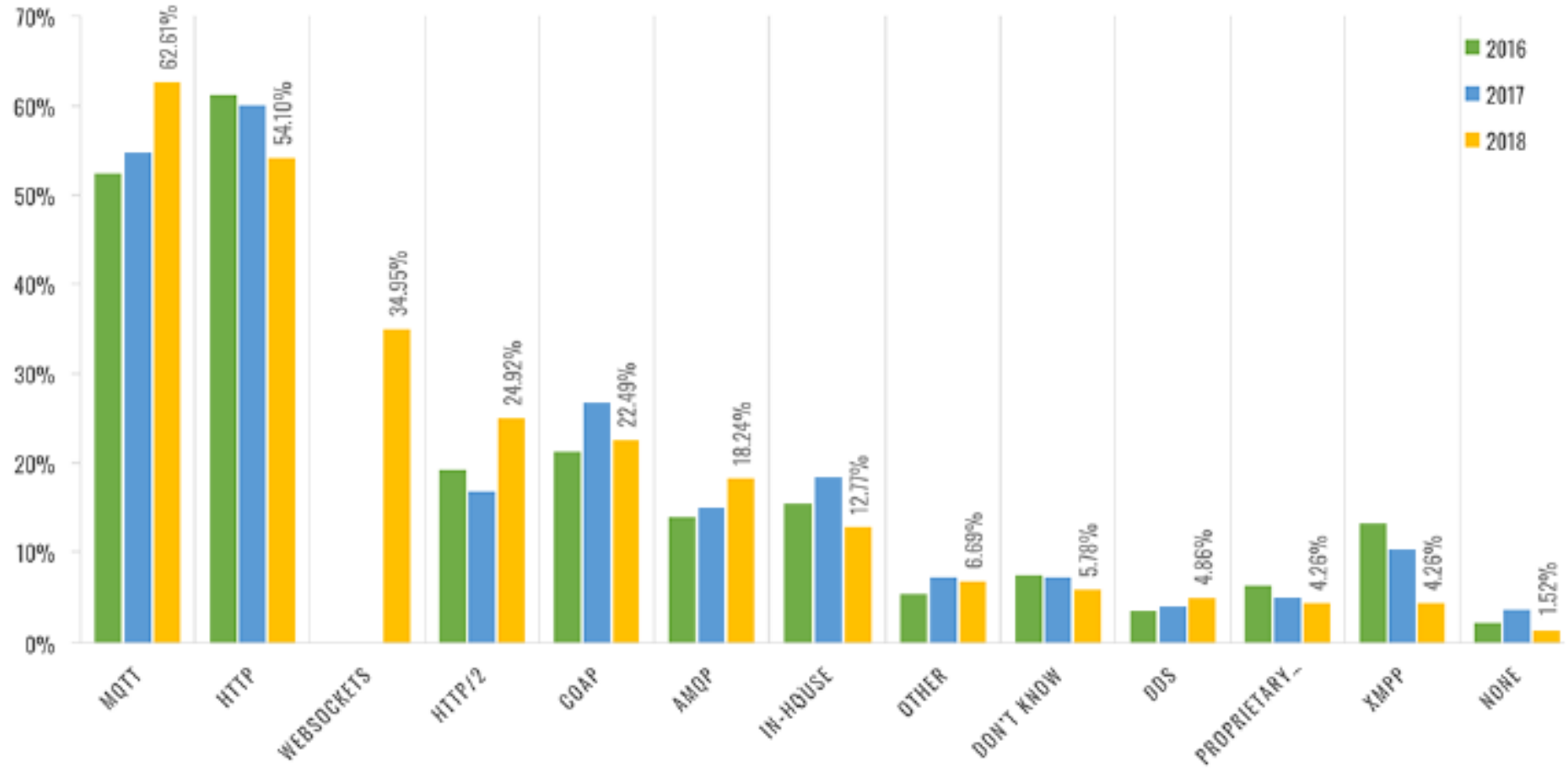
Market Solutions

	IOT Discovery Abstraction	Authentication, Authorization	Security end-2-end, secure on IOT and Dashboards	Open HW and Open SW	Integrated Community management	Data Types: IOT Devices, IOT App, Dashboard, Data	Data Type: Publish/share, Delegation, Consent and change	Data Type: Download and Delete	Auditing on Data Type Access	Open Source end-to-end	Scalability IOT	Visual Programming end-to-end applications	Advanced Smart City API, MicroServices	Multi Domain Semantic Platform	Standard based Modules and IOT, Open Devices	Resource Sharing	Data Analytics integrated	Dashboard H24/7, protected connection	Multi-protocol on IOT
		G				G	G	G	G										
Snap4City	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
KAA [53]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	N	(Y)	N	N	Y	Y
Thingsboard [55]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT,coap, http
IOT eclipse.org [56]	N	N	N	(Y)	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N	N	Y
IOT IGNITE [57]	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	N	N	N	N	N	Y	MQTT
FIWARE [47]	N	Y	N	Y	N	N	N	Y	N	Y	(Y)	(N)	Y	N	Y	N	N	Y	Y
ARM mbed IoT [48]	Y	Y	Y	Y	Y	N	(N)	N	Y	Y	Y	N	N	N	Y	N	N	Y	Limited
Airvantage [51]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT, HTTP
AWS [43]	Y	Y	Y	Y	N	Y	(N)	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
Azure IOT [44]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
PTC ThingWorkx [59]	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	N	Y	N	N	Y	Y
Bosch IoT Suite [58]	Y	Y	Y	Y	Y	(Y)	(N)	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Y
CISCO Jasper [55]	Y	Y	Y	Y	N	(Y)	(N)	N	Y	N	Y	N	N	N	N	--	(Y)	Y	N
Siemens MindSphere [60]	Y	Y	Y	(Y)	N	Y	(N)	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	Y
Carriots [54]	Y	Y	Y	(Y)	N	Y	N	N	Y	N	Y	N	N	N	--	N	N	Y	MQTT
Google IOT [45]	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP
Homekit Apple [50]	Y	Y	Y	Y	N	Y	N	N	Y	N	(Y)	N	N	N	N	Y	N	Y	Limited
Smarthing Samsung [52]	Y	Y	Y	Y	Y	Y	(Y)	Y	Y	N	(Y)	N	N	N	N	N	N	Y	Limited

Market Solutions

	IOT Discovery Abstraction	Authentication, Authorization	Security end-2-end, secure on IOT and Dashboards	Open HW and Open SW	Integrated Community management	Data Types: IOT Devices, IOT App, Dashboard, Data	Data Type: Publish/share, Delegation, Consent and change	Data Type: Download and Delete	Auditing on Data Type Access	Open Source end-to-end	Scalability IOT	Visual Programming end-to-end applications	Advanced Smart City API, MicroServices	Multi Domain Semantic Platform	Standard based Modules and IOT, Open Devices	Resource Sharing	Data Analytics integrated	Dashboard H24/7, protected connection	Multi-protocol on IOT
		G				G	G	G	G										
Snap4City	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
KAA [53]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	N	(Y)	N	N	Y	Y
Thingsboard [55]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT,coap, http
IOT eclipse.org [56]	N	N	N	(Y)	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N	N	Y
IOT IGNITE [57]	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	N	N	N	N	N	Y	MQTT
FIWARE [47]	N	Y	N	Y	N	N	N	Y	N	Y	(Y)	(N)	Y	N	Y	N	N	Y	Y
ARM mbed IoT [48]	Y	Y	Y	Y	Y	N	(N)	N	Y	Y	Y	N	N	N	Y	N	N	Y	Limited
Airvantage [51]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT, HTTP
AWS [43]	Y	Y	Y	Y	N	Y	(N)	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
Azure IOT [44]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
PTC ThingWorkx [59]	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	N	Y	N	N	Y	Y
Bosch IoT Suite [58]	Y	Y	Y	Y	Y	(Y)	(N)	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Y
CISCO Jasper [55]	Y	Y	Y	Y	N	(Y)	(N)	N	Y	N	Y	N	N	N	N	--	(Y)	Y	N
Siemens MindSphere [60]	Y	Y	Y	(Y)	N	Y	(N)	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	Y
Carriots [54]	Y	Y	Y	(Y)	N	Y	N	N	Y	N	Y	N	N	N	--	N	N	Y	MQTT
Google IOT [45]	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP
Homekit Apple [50]	Y	Y	Y	Y	N	Y	N	N	Y	N	(Y)	N	N	N	N	Y	N	Y	Limited
Smarthing Samsung [52]	Y	Y	Y	Y	Y	Y	(Y)	Y	Y	N	(Y)	N	N	N	N	N	N	Y	Limited

	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%



	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.

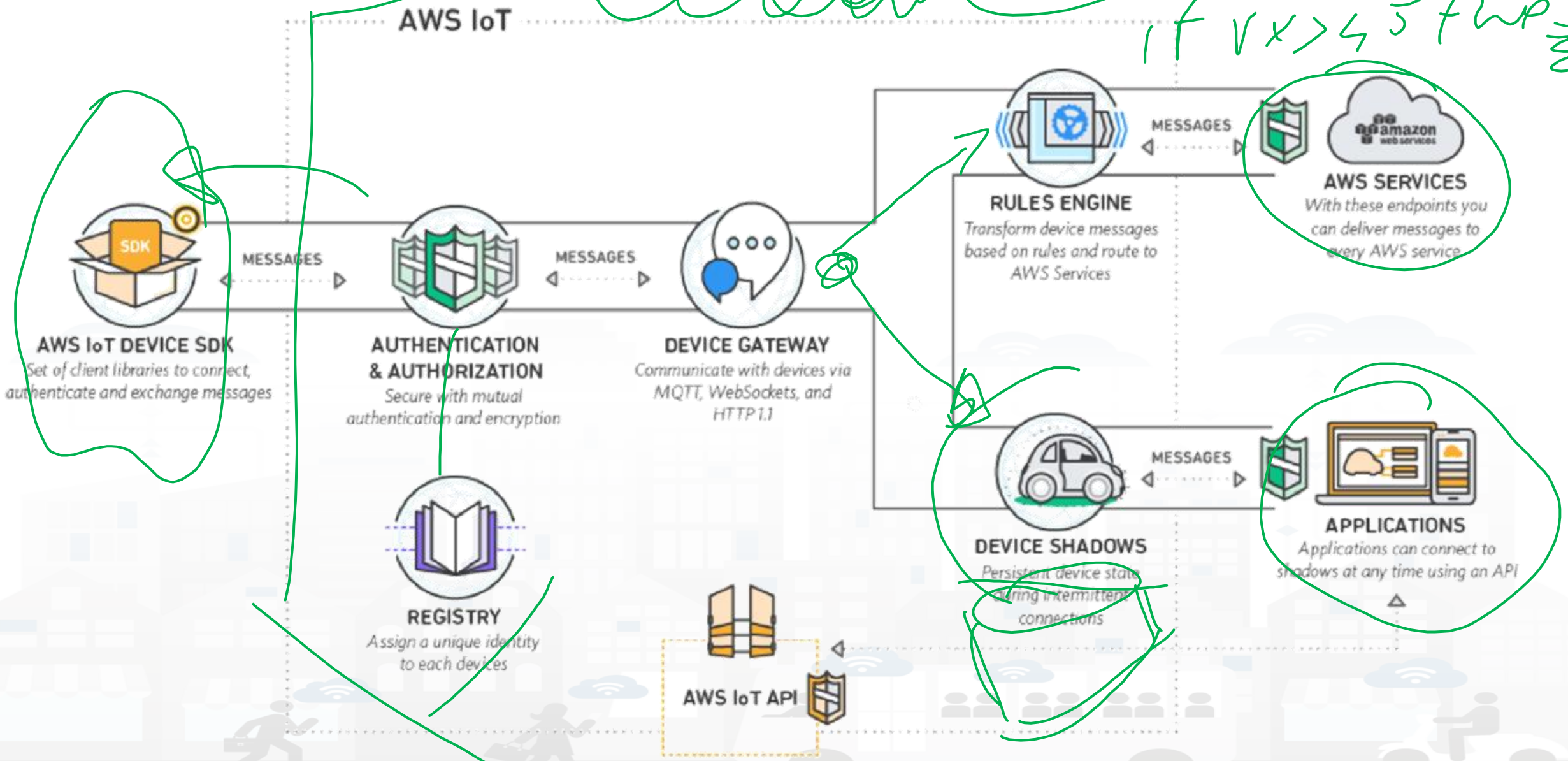
	Azure IoT	AWS	Google IoT
Edge			
Storage	Blob, CosmosDB, SQL		
Big Data			
Data Visualization	Power Bi		
Artificial Intelligence			
Intelligence API	Language, Speech, Vision, Knowledge		

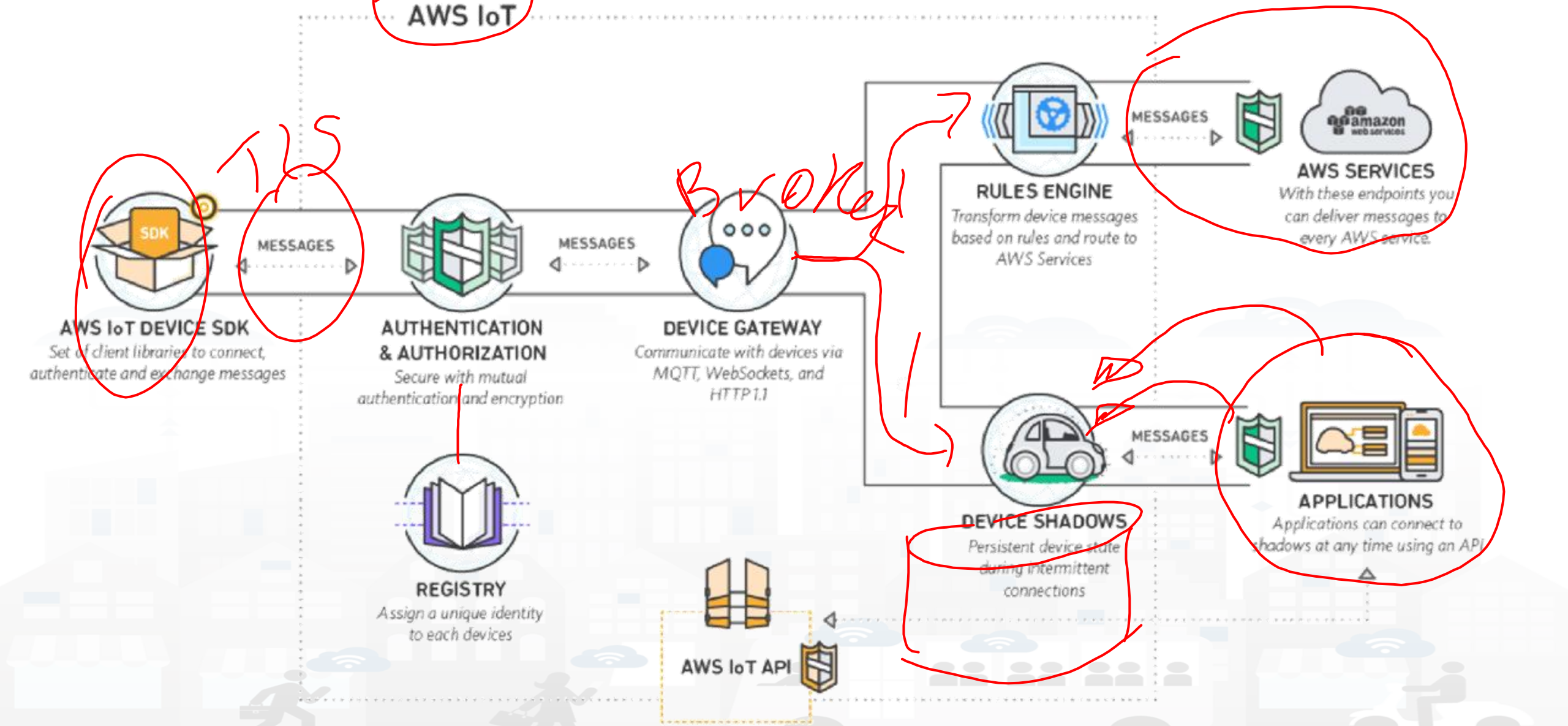
	Azure IoT	AWS	Google IoT
Protocolli	MQTT, AMQP, MQTT on WebSocket, HTTPS, AMQP on WebSocket	MQTT, MQTT on WebSocket, HTTPS	MQTT, HTTP
Communication Patterns	Telemetry, Query, Notification, Command	Telemetry, Query, Notification, Command	Telemetry, Query, Notification, Command

	Azure IoT	AWS	Google IoT
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

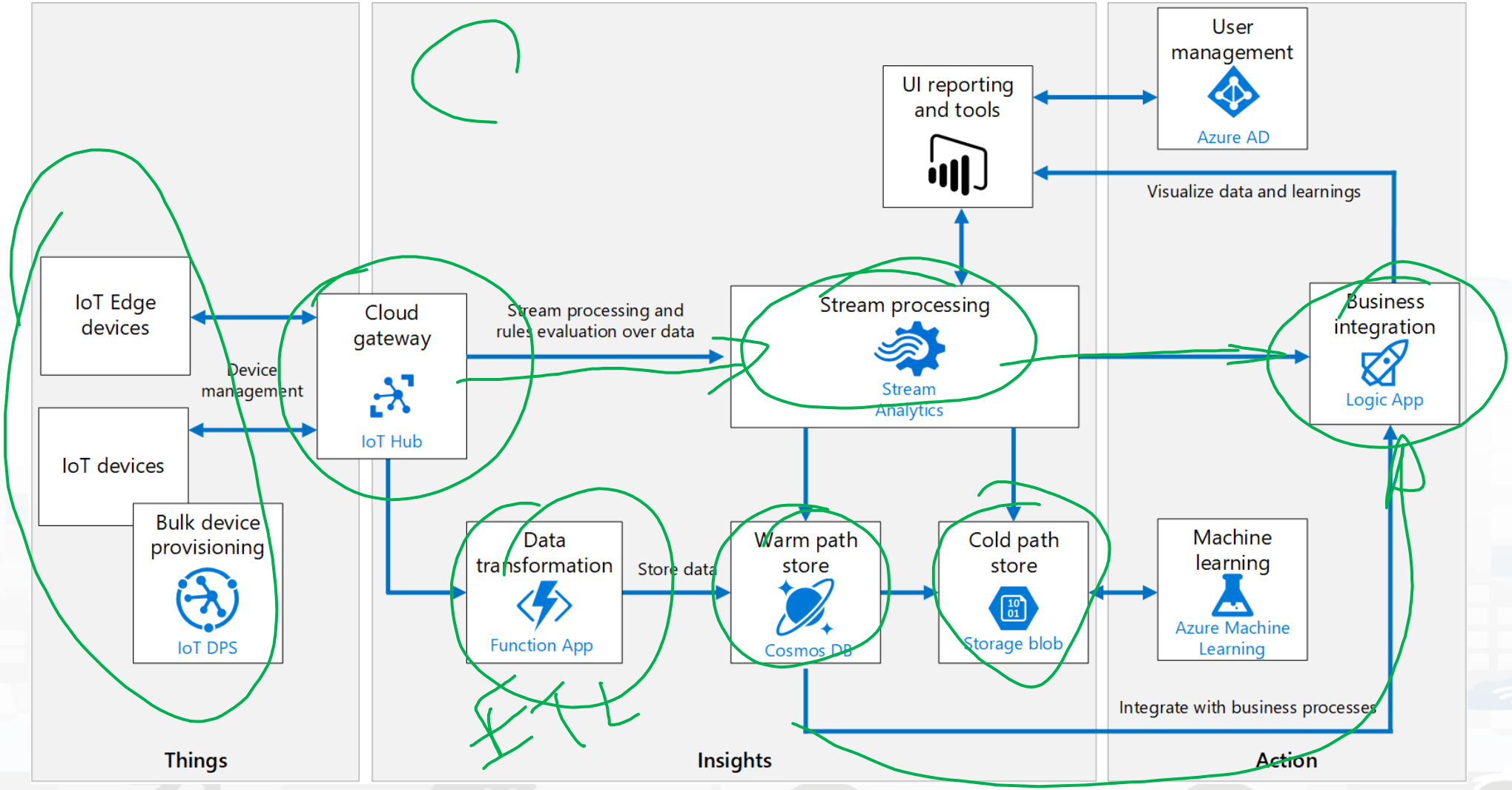
	Azure IoT	AWS	Google IoT
Scalability	Scaling da configurare mediante funzione	Servizio di scaling automatico	Servizio di scaling automatico
Rimborsi	10% di rimborso fino al 99%, al di sotto viene rimborsato il 25%	10% di rimborso fino al 99%, al di sotto viene rimborsato il 30%	10% di rimborso fino al 99%, nella fascia fino al 95% viene restituito il 25% e al di sotto di questa il 50%

	Azure 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

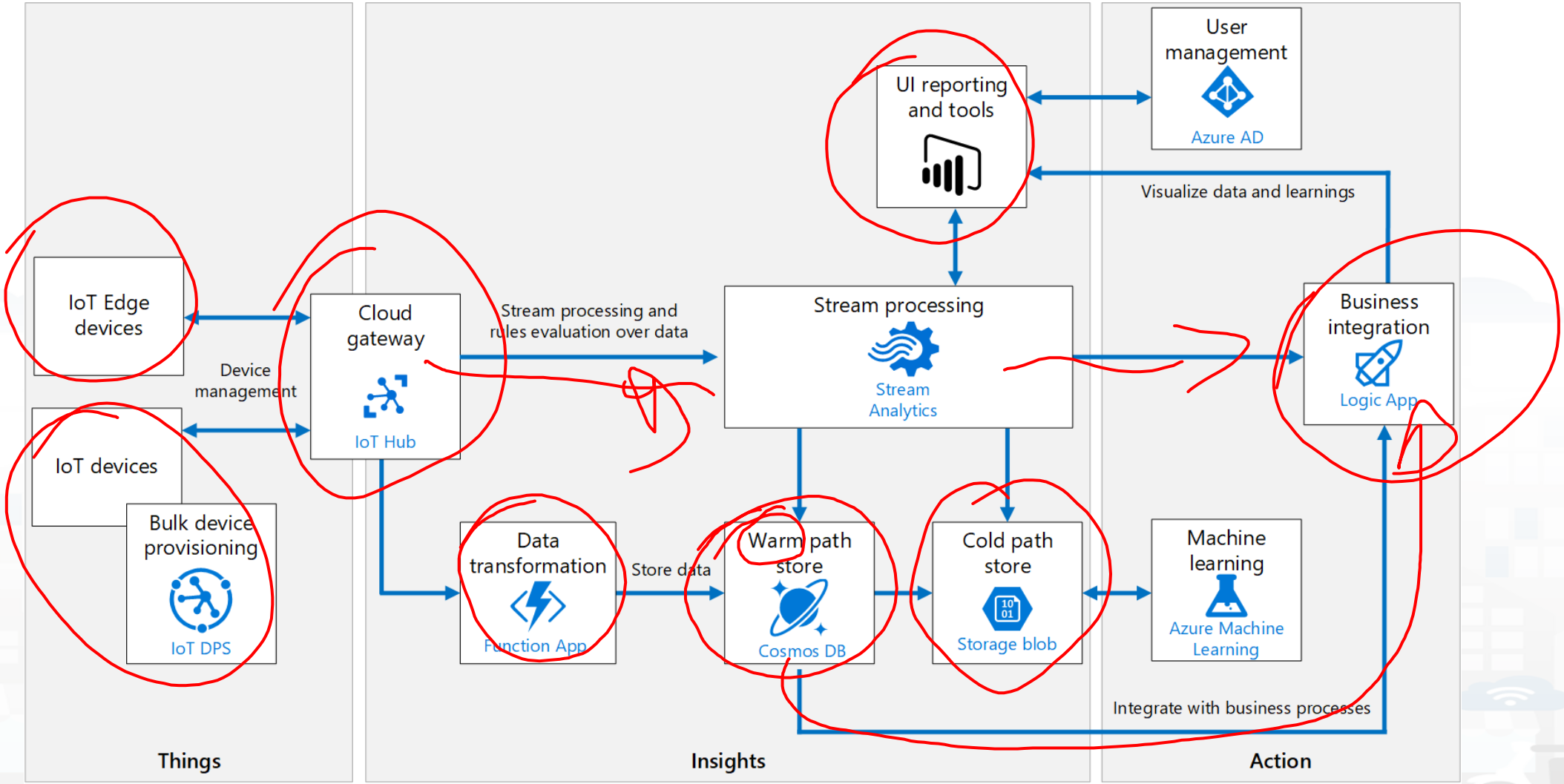

AWS IoT
SDK
MESSAGES
MESSAGES
MESSAGES
MESSAGES
AWS IoT DEVICE SDK
Set of client libraries to connect, authenticate and exchange messages
AUTHENTICATION & AUTHORIZATION
Secure with mutual authentication and encryption
DEVICE GATEWAY
Communicate with devices via MQTT, WebSockets, and HTTP 1.1
RULES ENGINE
Transform device messages based on rules and route to AWS Services
amazon web services
AWS SERVICES
With these endpoints you can deliver messages to every AWS service
DEVICE SHADOWS
Persistent device state during intermittent connections
APPLICATIONS
Applications can connect to shadows at any time using an API
REGISTRY
Assign a unique identity to each devices
AWS IoT API


AWS IoT
TLS
Broker
SDK
MESSAGES
MESSAGES
MESSAGES
MESSAGES
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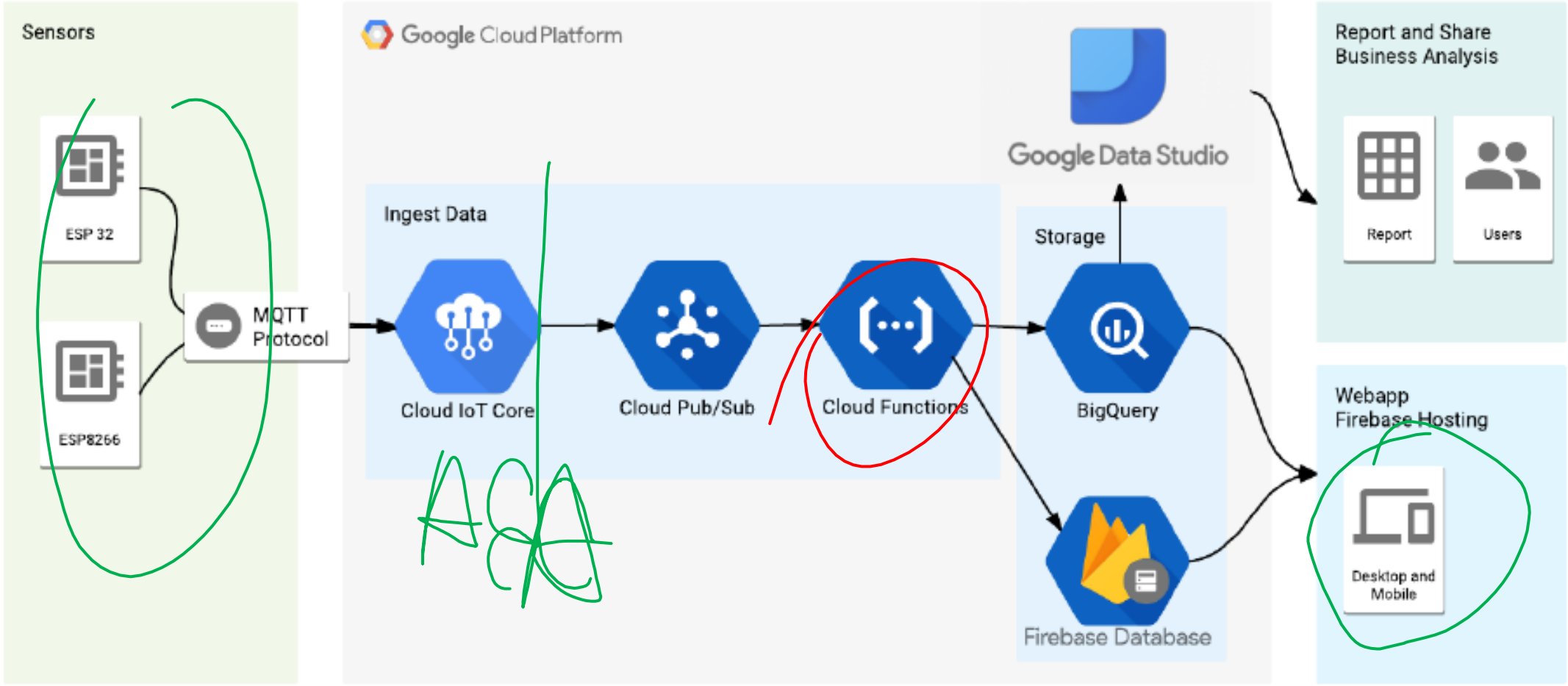
Azure Microsoft IoT (1)



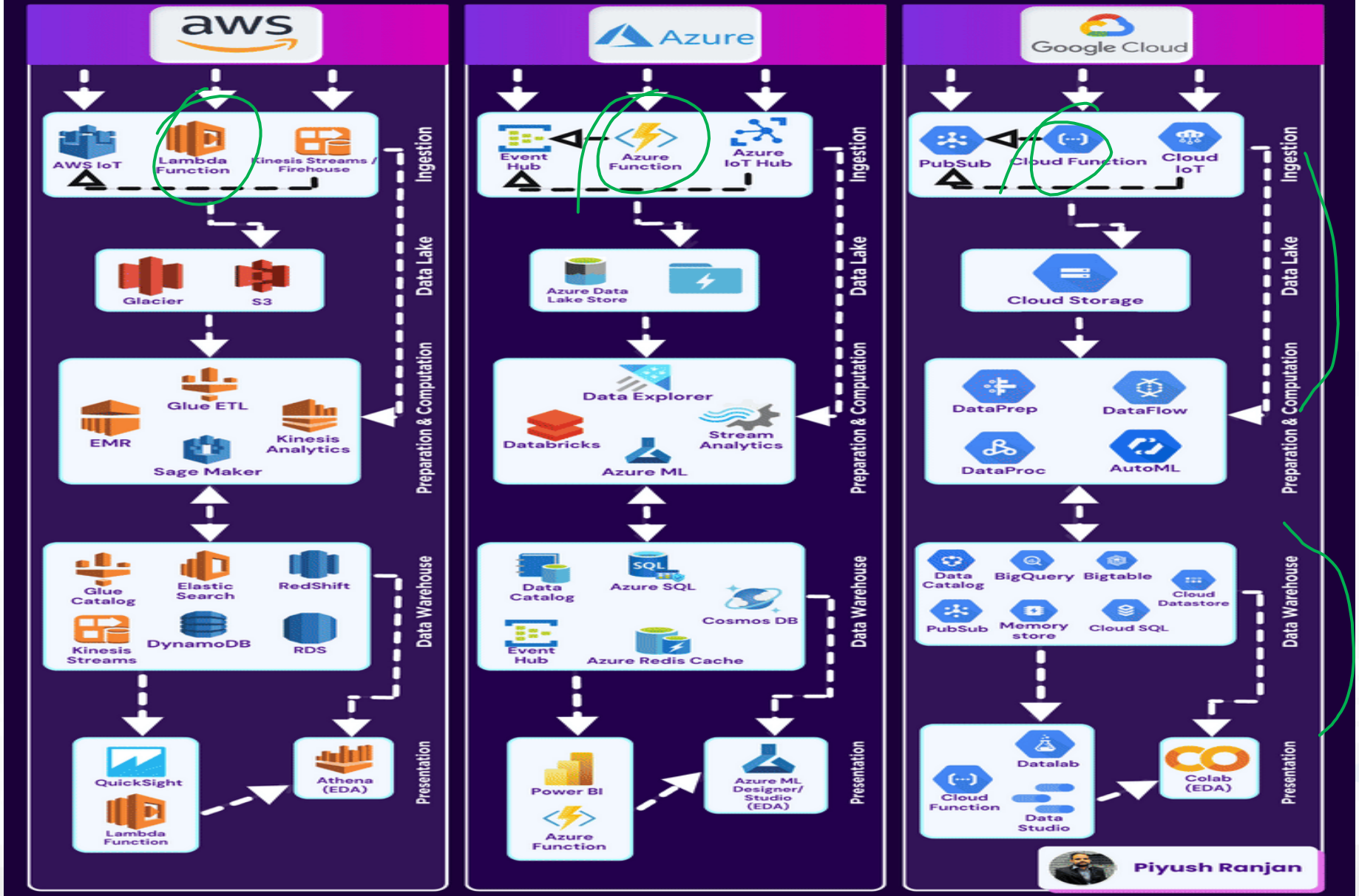
Azure Microsoft IoT (1)

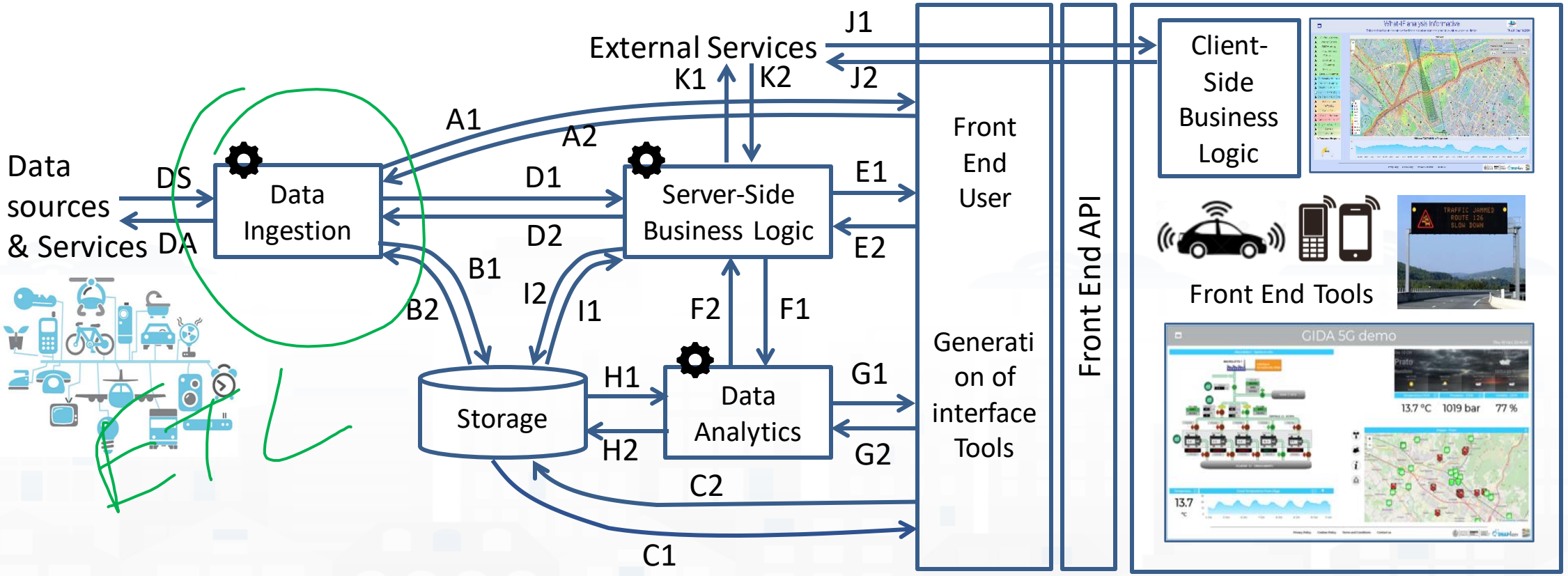


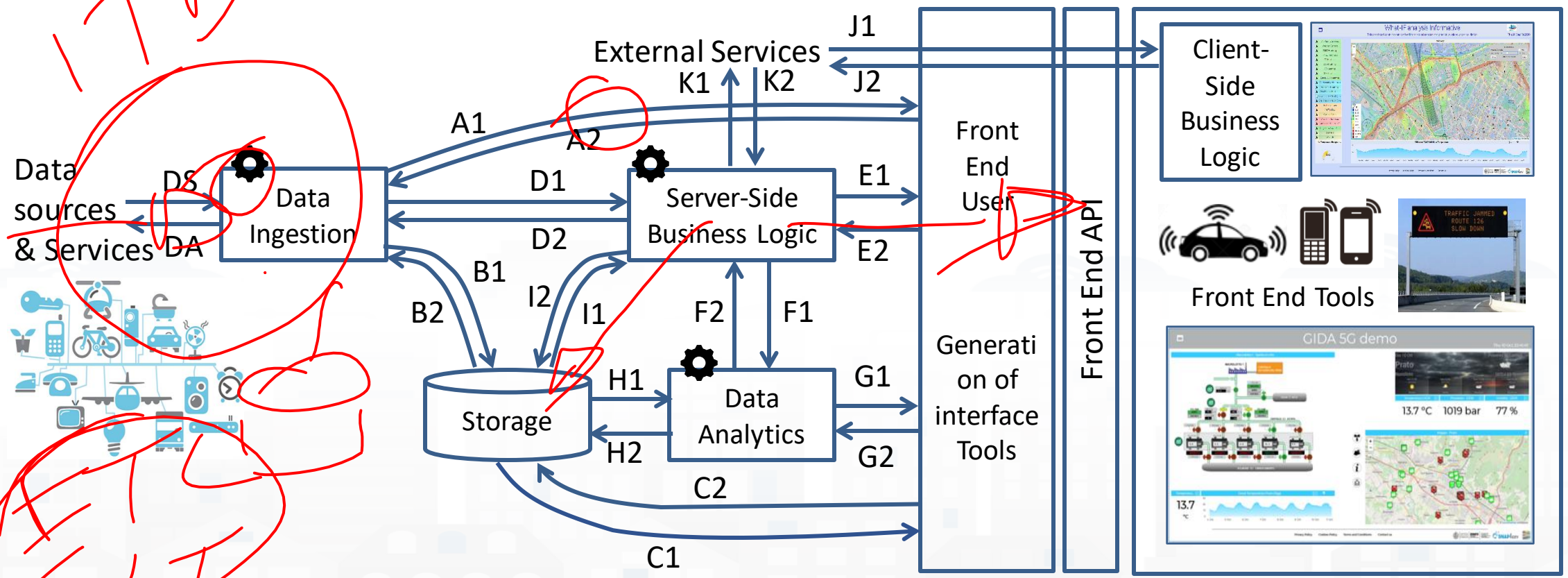
Google IoT (1)


Sensors
ESP 32
ESP8266
MQTT Protocol
Google Cloud Platform
Ingest Data
Cloud IoT Core
Cloud Pub/Sub
Cloud Functions
Storage
Google Data Studio
BigQuery
Firebase Database
Report and Share Business Analysis
Report
Users
Webapp Firebase Hosting
Desktop and Mobile

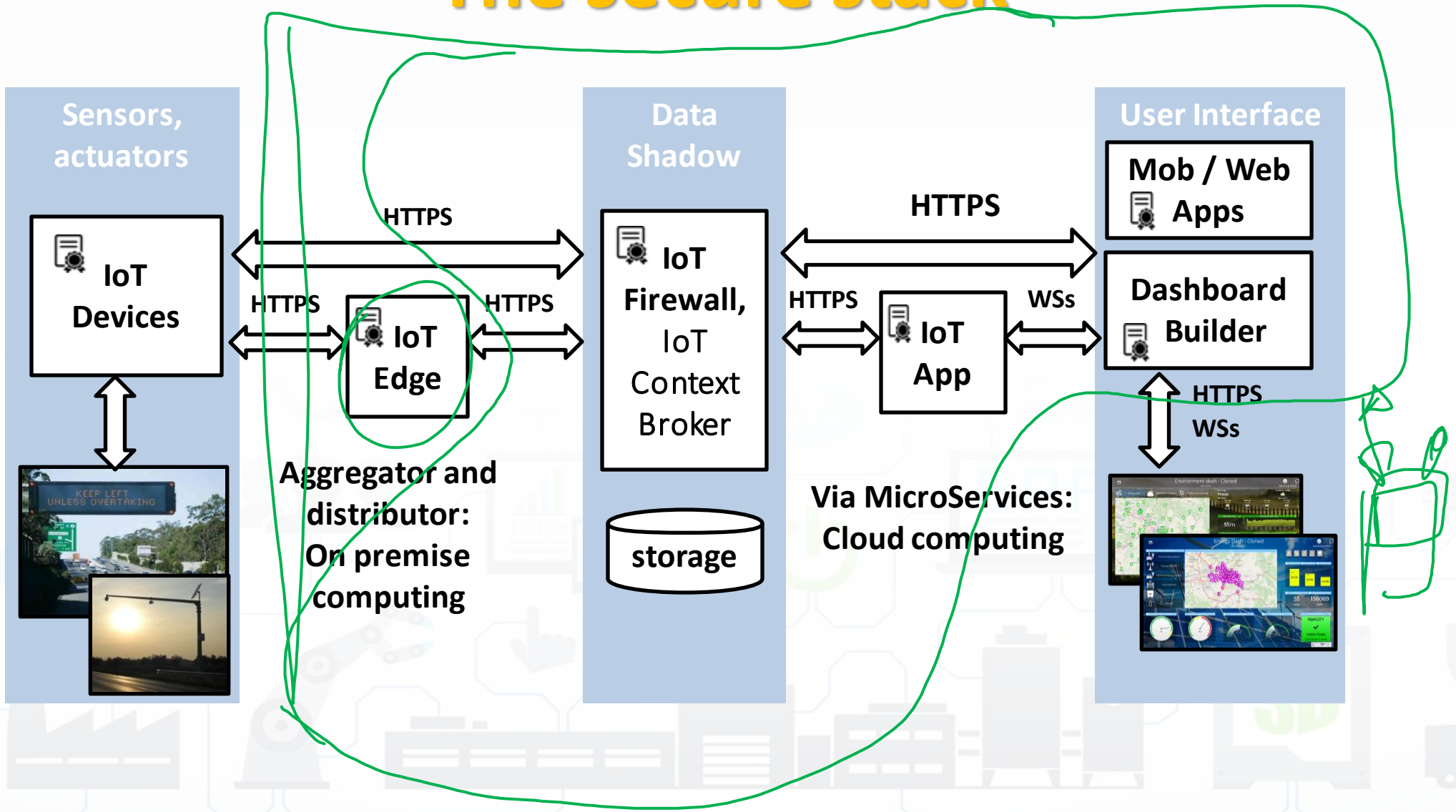
Data Pipelines on AWS, Azure and GCP




External Services
J1
J2
K1
K2
Front End User
Client-Side Business Logic
A1
A2
Data sources & Services
DS
DA
Data Ingestion
D1
D2
Server-Side Business Logic
E1
E2
B1
B2
I2
I1
F2
F1
Front End API
Front End Tools
TRAFFIC JAMMED ROUTE 126 SLOW DOWN
GIDA 5G demo
Storage
H1
H2
Data Analytics
G1
G2
Generation of interface Tools
C2
C1


Data sources & Services
DS
DA
Data Ingestion
A1
A2
External Services
J1
J2
K1
K2
D1
D2
Server-Side Business Logic
E1
E2
B1
B2
I2
I1
F2
F1
Storage
H1
H2
Data Analytics
G1
G2
C2
C1
Front End User
Generation of interface Tools
Front End API
Client-Side Business Logic
Front End Tools
GIDA 5G demo

The secure stack

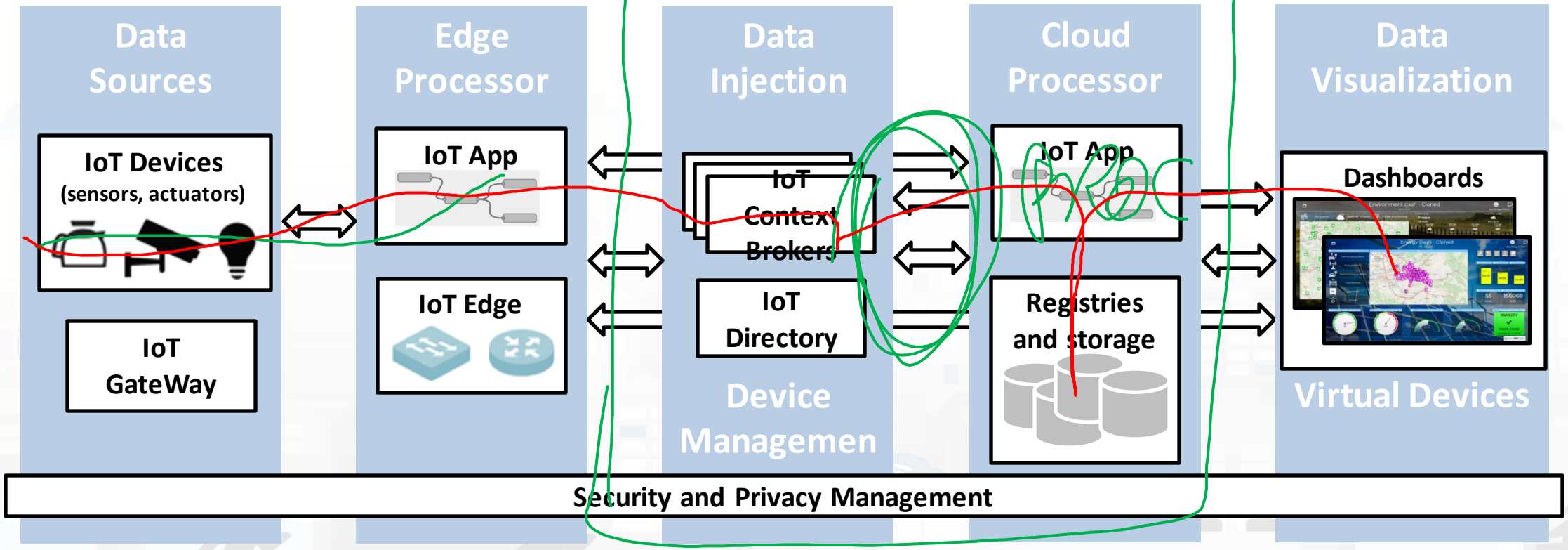


Complexity in Smart City IOT Platforms

End to End security

- From IOT Devices to Dashboard (user interface)

- H2M
- M2M



UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

Snap4City Architectures

https://www.snap4City.org **https://www.Km4City.org**

Parte: 4b (2024)



SOME RIGHTS RESERVED
BY NC ND


Snap4City
Development Environment
From Data to Smart Cities. Together.
INTEROPERABLE • INTELLIGENT • SUSTAINABLE • FOR A BETTER TOMORROW
Parking
Waste Management
Smart Lighting
Environment Monitoring
Mobility
Ports & Logistics
Energy Management
AI & MLOps Agentic AI
SMART PEOPLE SMART PLACES SMART SOLUTIONS
Snap4City Development Environment
Home
Dashboards
Data Models
Applications
Tools
Search anything...
Data Interoperability
Node-RED
Python
Sensor Input
Filter
Transform
Enrich
Save to DB
Publish
Read data from IoT devices
import snap4city as s4c
data = s4c.get_sensors_data("parking")
df = s4c.to_dataframe(data)
Process and publish
result = df[df['status'] == 'free']
s4c.publish("smartcityparking", result)
City Live Map
Total Sensors
1,428
+12%
Active Services
24
+6%
CO2 (avg)
18.5 µg/m³
-6%
Energy Consumption
2.4 GWh
-11%
Air Quality Trend
Last 24h
Traffic Flow
Cars
Buses
Bikes
Data Models
Device
Location
CityEntity
Observation
Service
Event
User
Dictionary & Ontology
Schemas (JSON-LD)
Domain Dictionary
Ontologies (SAREF)
Linked Data
AI Tools & MLOps
Data Prep
Training
Validation
Model Registry
Deployment
Monitoring
Retraining
AutoML
Experiment Tracking
Model Versioning
MLOps Pipelines
Scalable Deployment
Visual Editor
Map
Chart
KPI Card
Table
Text
Image
Container
Drag & Drop Widget
MCP Agentic Tools
Task Automation
City Data (real-time)
Dashboards & Reports
AI Agent (MCP)
APIs & Services
Memory (context)
Actions & Tools
Connect intelligent agents. Connect data, tools and services.
SAME DATA BRIGHTER CITIES
SnapAdvisor
AI Copilot
How can I help you today?
I can assist with development, data analysis, city operations and smart city solutions.
Create an AI workflow for city data
Build an MCP agent for smart mobility
Set up an MLOps pipeline
Generate insights from urban data
Help me with model deployment
Support decision making with AI
Ask SnapAdvisor...
STANDARDS
REAL-TIME DATA
BUILD > INTEGRATE > ANALYZE > DEPLOY > SMARTER CITIES
SCALABLE SOLUTIONS
PEOPLE-CENTRIC SOLUTIONS

THE POWER OF AGENTIC AI AT THE SERVICE OF YOUR OPERATIONS AND PLANS

100% OPEN SOURCE

Powered by FIWARE

FREE TRIAL

PEN Test Passed

EU GDPR COMPLIANT

SNAP4 Appliances and Dockers Installations

EUROPEAN OPEN SCIENCE CLOUD

Node-RED

JS Foundation

EØ15 digital ecosystem

NVIDIA

UNIVERSITÀ DEGLI STUDI FIRENZE | DINFO | DISIT | SNAP4CITY | KM4CITY

OPERATION AND PLAN - CONTROL ROOMS - DECISION SUPPORT SYSTEMS - WHAT-IF ANALYSIS - OPTIMIZATION - APPLICATIONS -AGENTS

SMART ASSET

SMART MOBILITY

SMART PARKING

SMART LIGHT

SMART WASTE

SMART TOURISM

SNAPADVISOR & COPILOT

AGENTIC AI

- DEVELOMENT ENVIRONMENT AND METHODOLOGY
- VISUAL PROGRAMMING, ML, AI, HPC
- TRAINING COURSES

SMART CITY LIVING LAB

LOW-CODE DEVELOPMENT, VISUAL PROGRAMMING, SMART APPLICATION DEV., DIGITAL TWIN DEV. PLATFORM, PROCESSING LOGIC, MICROSERVICES API-DRIVEN DEV., EDGE & CLOUD DEV.

ARTIFICIAL INTELLIGENCE, AI-POWERED DIGITAL TWIN, ADVANCED ANALYTICS, PREDICTTION, OPTIMISATION, SIMULATION, MACHINE LEARNING, GENERATIVE AI, AGENTIC AI, AI AGENTS, RAG, GRAPH AI, MLOPS

KNOWLEDGE GRAPH, SEMANTIC KNOWLEDGE, KNOWLEDGE-DRIVEN, CONTEXT-AWARE DATA, SEMANTIC REASONING, DATA HARMONIZATION

INTEROPERABILITY, SEMANTIC INTEROPERABILITY, CROSS-PLATFORM, OPEN STANDARDS VENDOR-AGNOSTIC, LEGACY SYSTEMS

ANY DATA INGESTION, REAL-TIME, INTEGRATION, IOT/WOT, HETEROGENEOUS DATA, EDGE-TO-CLOUD DATA INTEGRATION, BIDIRECTIONAL EVENT DRIVEN

FULL INTEROPERABILITY, ANY: DATA, BROKERS, NETWORKS AND VERTICALS

EUROPEAN DATA SPACES

PUBLIC DATA SPACES

PRIVATE DATA SPACES

SECTORAL DATA SPACES

DATA SPACES

INDUSTRY 4.0

SHARING

LIGHT

ENVIRONMENT

SHOPPING

SECURITY

CONTROL ROOM

SATELLITE

AGRICULTURE

ENERGY

MOBILE

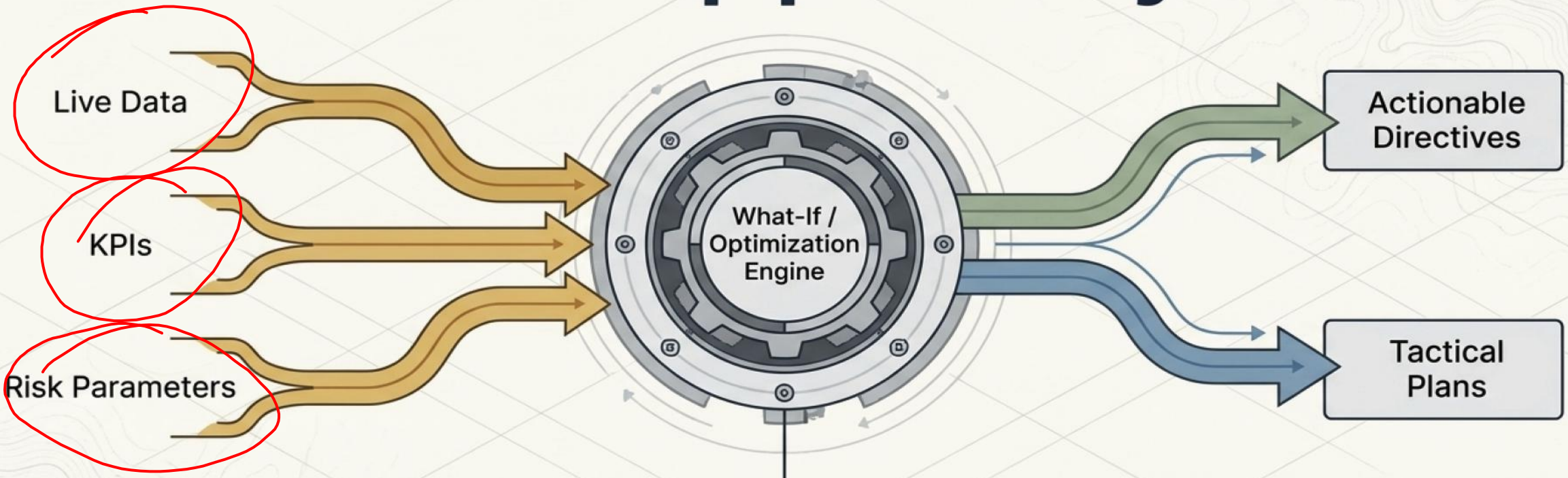
WASTE

BUILDING

TRANSPORT

TOURISM

Decision Support Systems

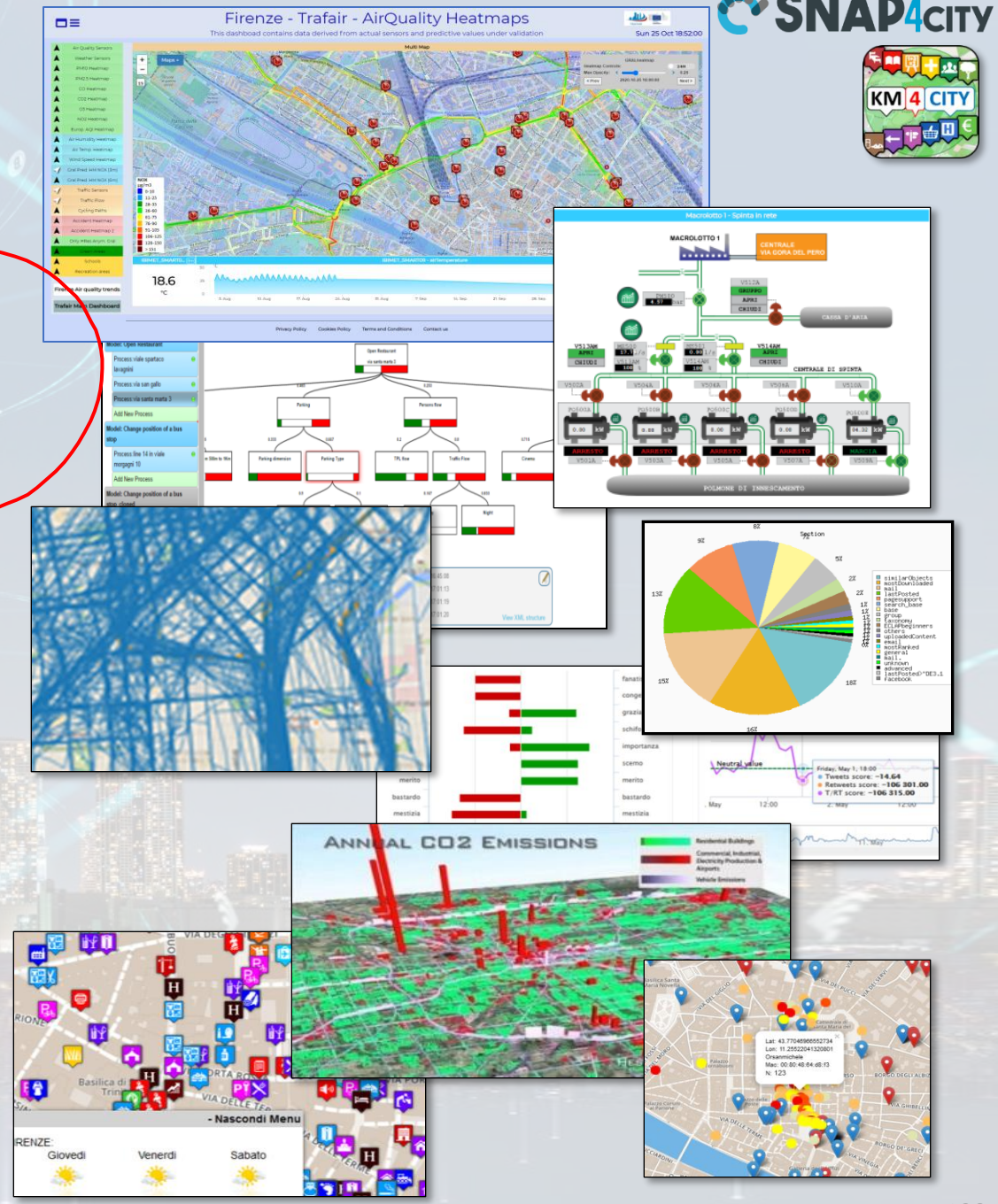


What-If Analysis:
Grounded on robust predictive algorithms and simulations.

Scenario-Based Optimization:
Test traffic light plan optimizations digitally. Evaluate major traffic infrastructure changes. Assess tactical risks and generate prescriptions before spending public funds.

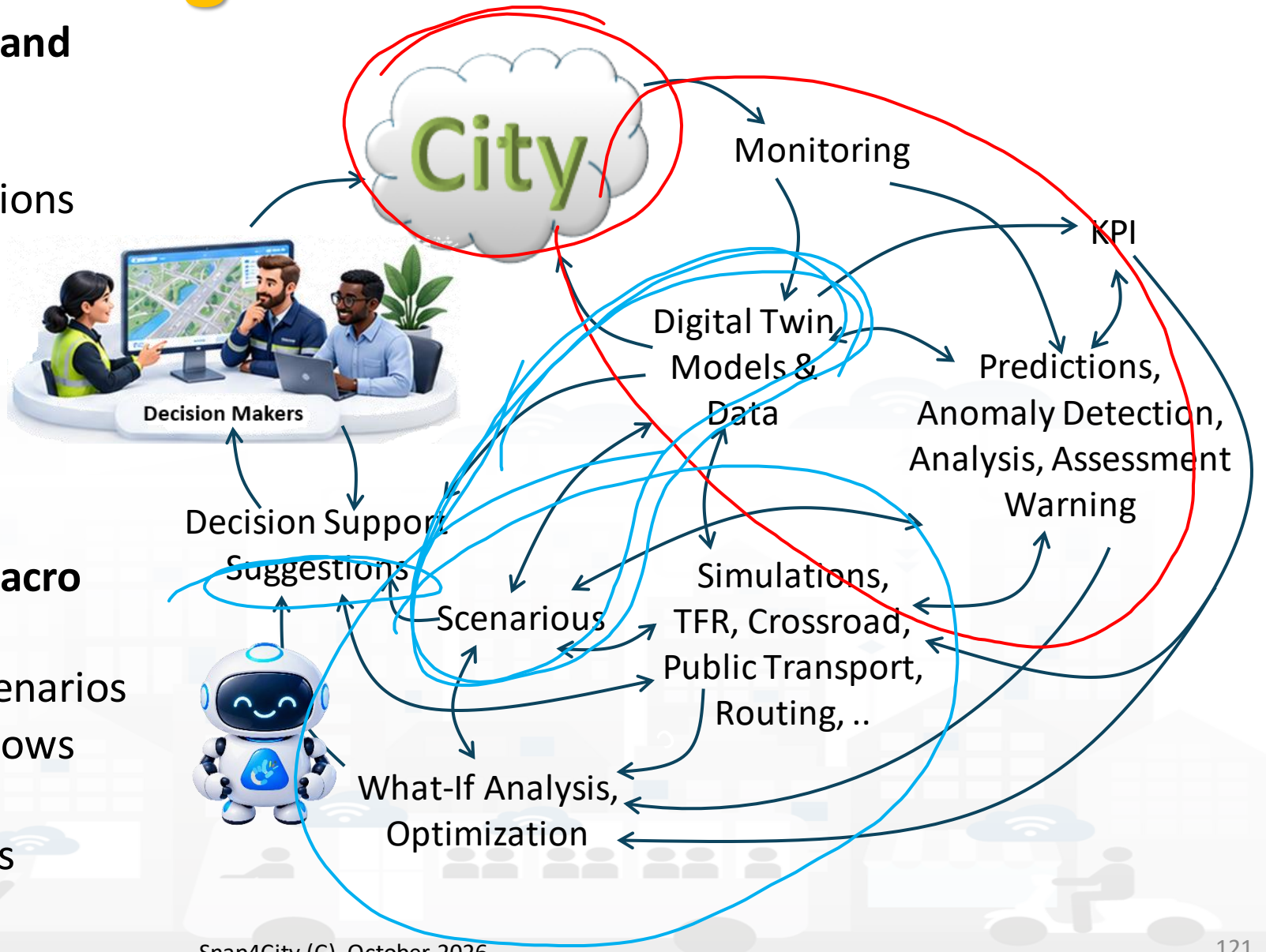
Data Driven Decision Support

- Decision Support system
- Assessment / Strategies
- Data Rendering, visual analytics
- Data Processing
- Data aggregation, Storage, indexing
- Data Ingestion

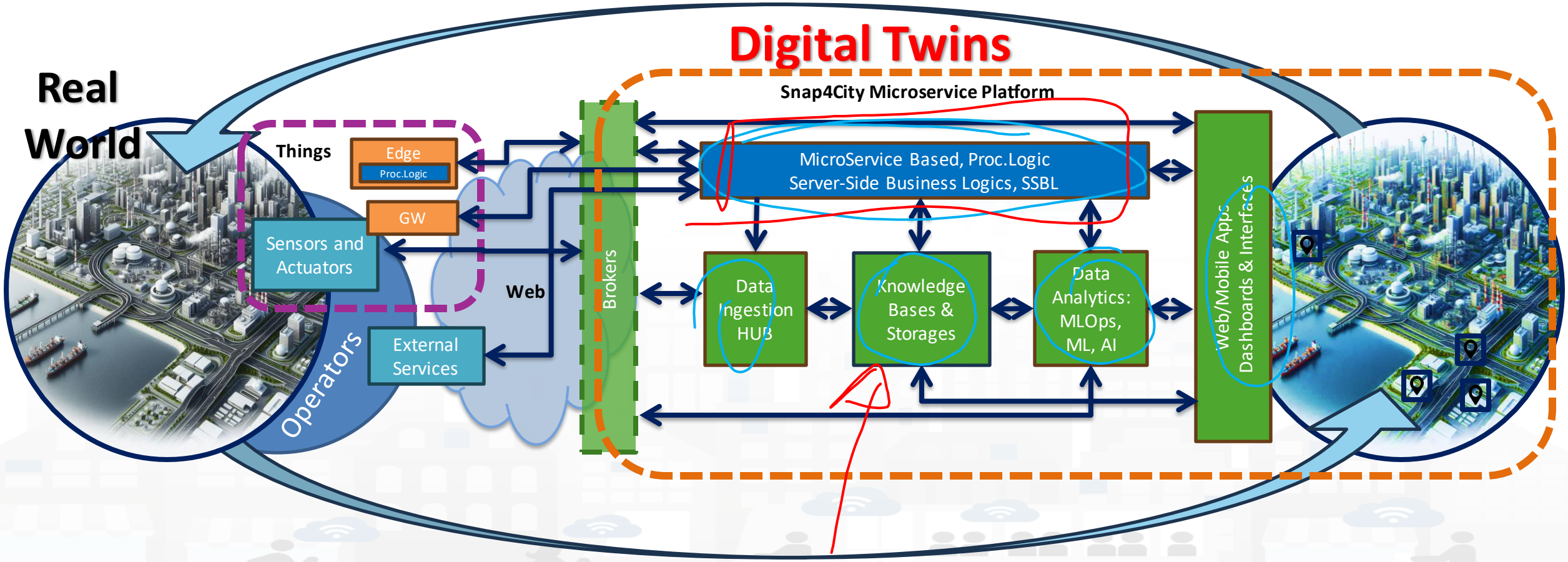


Agentic Tasks

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Early warning on critical conditions
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders



Digital Twin Development Platform

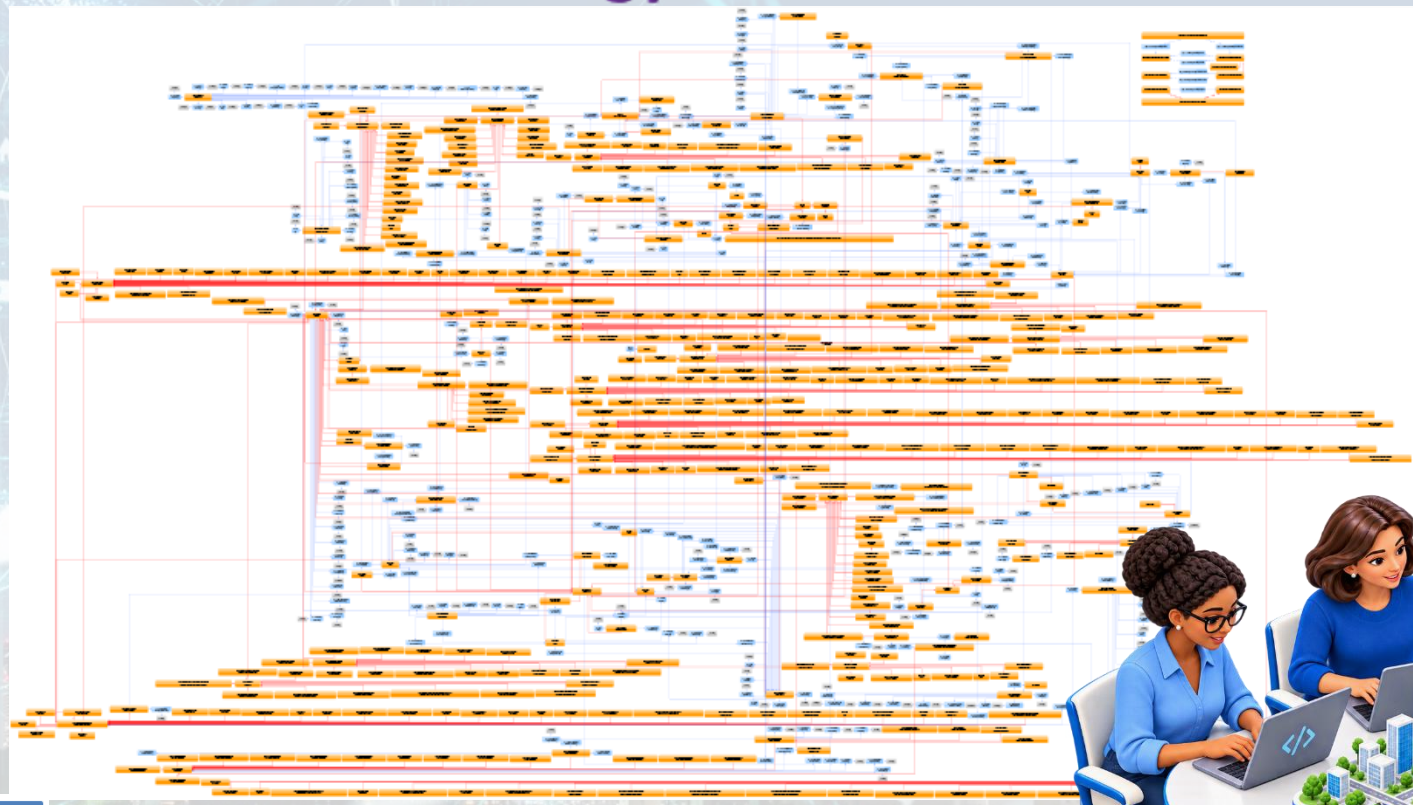


Expert System semantic queries

via:

- **Smart City API** for Apps and third party
- **MicroServices** data driven develop via visual language Node-RED

Extensible ontology License Free: 1.6.8





01	**Interoperability:** any format, any protocol, any API, visual programming node-red, Python, brokers, etc. Server Sides Business Models, ETL, ELT, ..
02	**Data Model:** standard and custom data models, dictionary, ontology; Data Spaces, MDS; data models FIWARE, etc.

Linked Open Data

https://www.snap4city.org/19

Km4City Ontology elements 1.6.8

- **Km4C**: Km4City 1.6.8
- Using
  - **DCTERMS**: for metadata Dublin Core Metadata Initiative
  - **FOAF**: friends of a friends
  - **Good Relation**: entities relationships
  - **iot-lite**: IOT Vocabuary
  - **OTN**: Ontology of Transportation Networks
  - **OWL-Time**: time reasoning
  - **SAREF** Smart Appliances REFerence extension for building devices available at https://saref.etsi.org/saref4bldg/
  - **Schema.org** for people and organizations
  - **SSN**: Semantic Sensor Network Ontology (see https://www.w3.org/TR/vocab-ssn/
  - **WGS84** Datum of Geo-Objects
  - **GTFS**, General Transit Feed Specification, and **Transmodel**, for public transport infrastructures: lines/rides time schedules, real-time records, paths, etc.;
  - **BOT**: Building Topology Ontology. https://w3c-lbd-cg.github.io/bot/
  - **S4CITY**: SAREF extension for Smart City. https://saref.etsi.org/saref4city/v1.1.2/



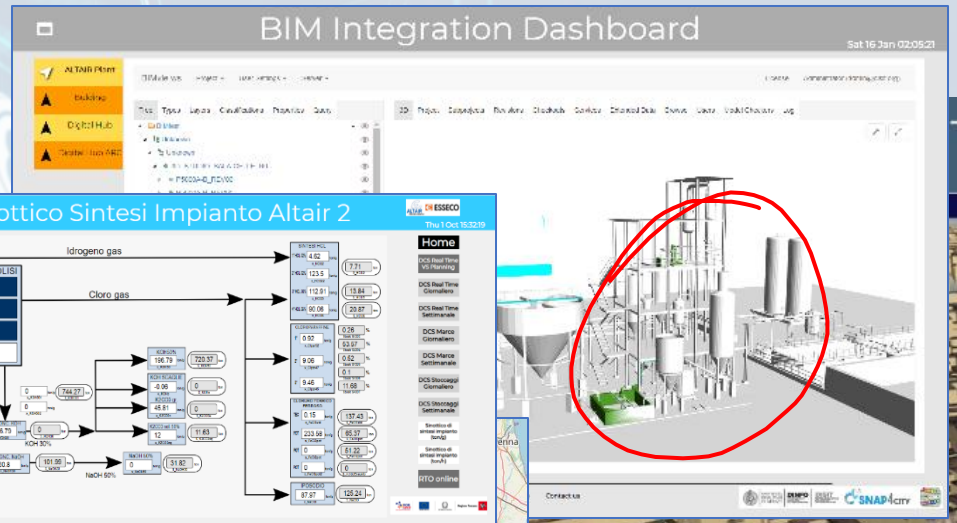


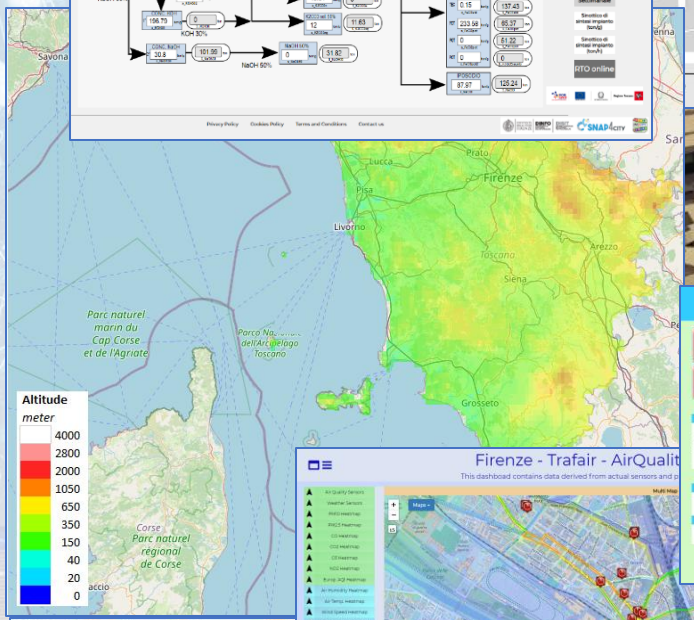
High Level Types

Snap4City (C), October 2026

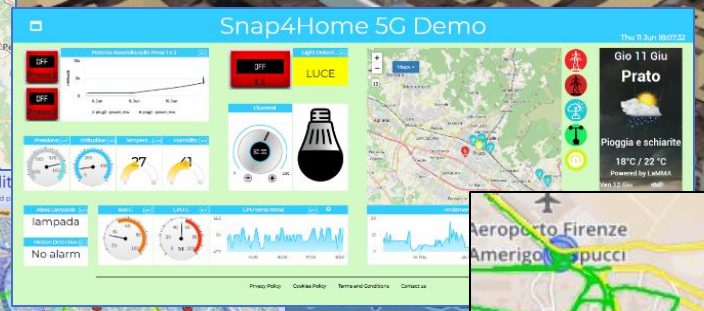
- POI, IOT Devices, shapes,..
  - ***FIWARE Smart Data Models,***
  - ***IoT Device Models***
  - ***Any custom data model***
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, any kind..
- traffic flow, typical trends, ..
- Vector fields + heatmaps, ..
- trajectories, events, workflow, ..
- 3D Models, BIM, Digital Twins, ..
- OD Matrices of several kinds, ..
- Dynamic icons/pins, ..
- Synoptics, animations, ..
- KPI, personal KPI,..
- social media data, TV Stream,
- routing, multimodal, constraints, ..
- scenarios, ….
- etc.





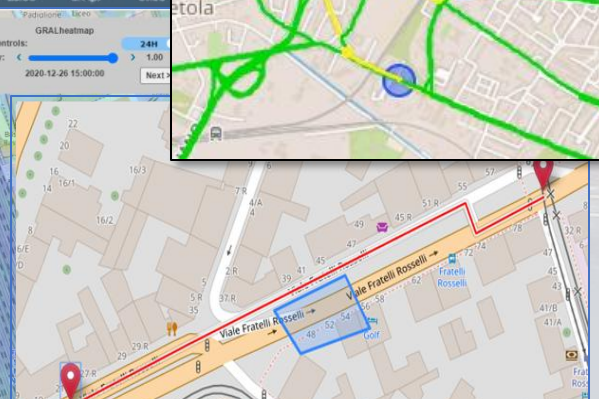












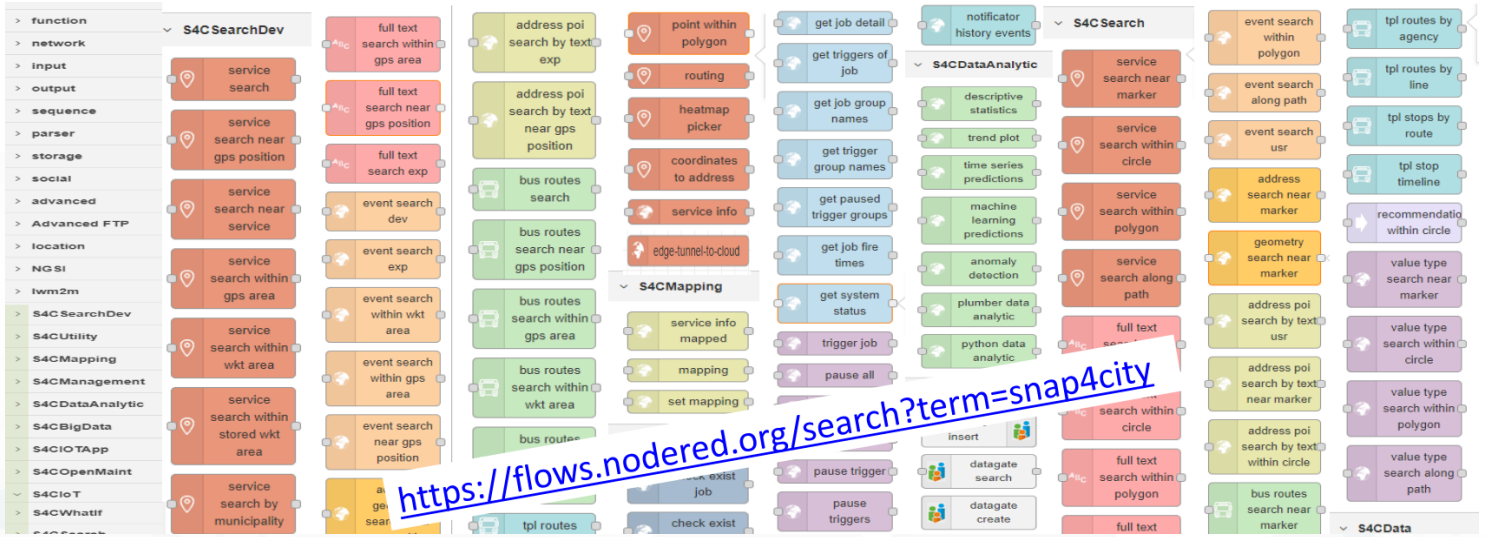
02	**Data Model:** standard and custom data models, dictionary, ontology; Data Spaces, MDS; data models FIWARE, etc.

Visual development with room for custom code

Reusable Node-RED microservices

Compose ingestion and processing flows.

Add Python or R analytics and connect external services through APIs.

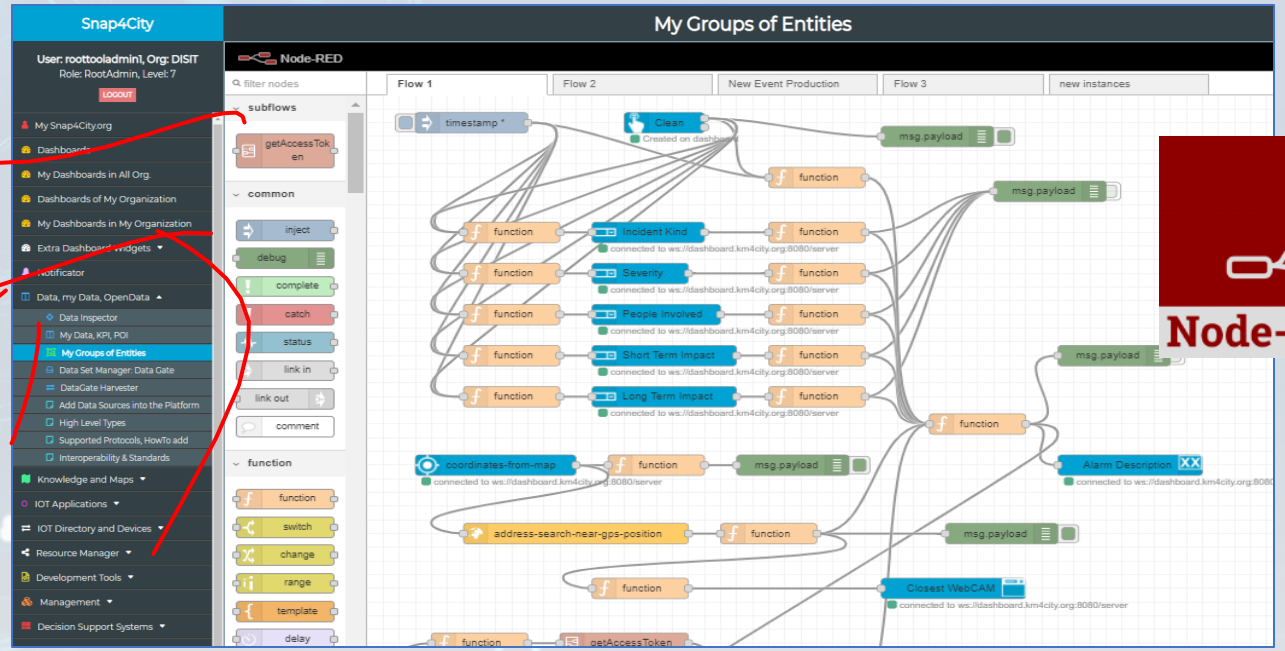


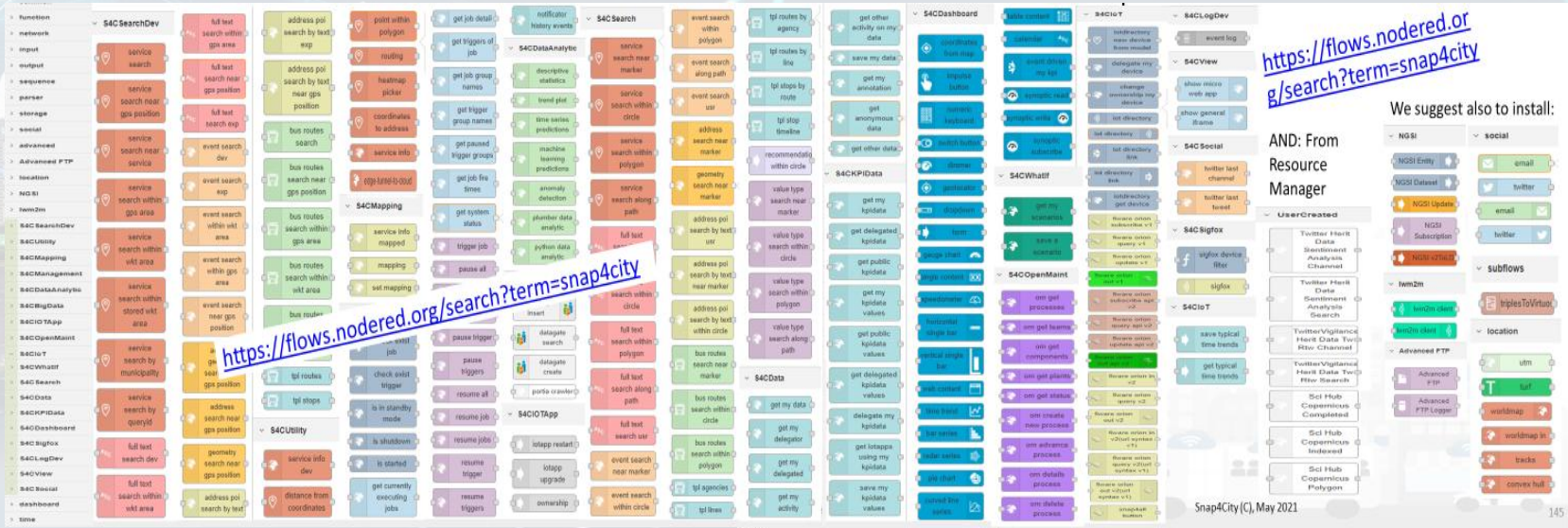
A shared toolbox for developers and system integrators

© Snap4City, Nov. 2026

Ingestion, aggreg. → exploitation

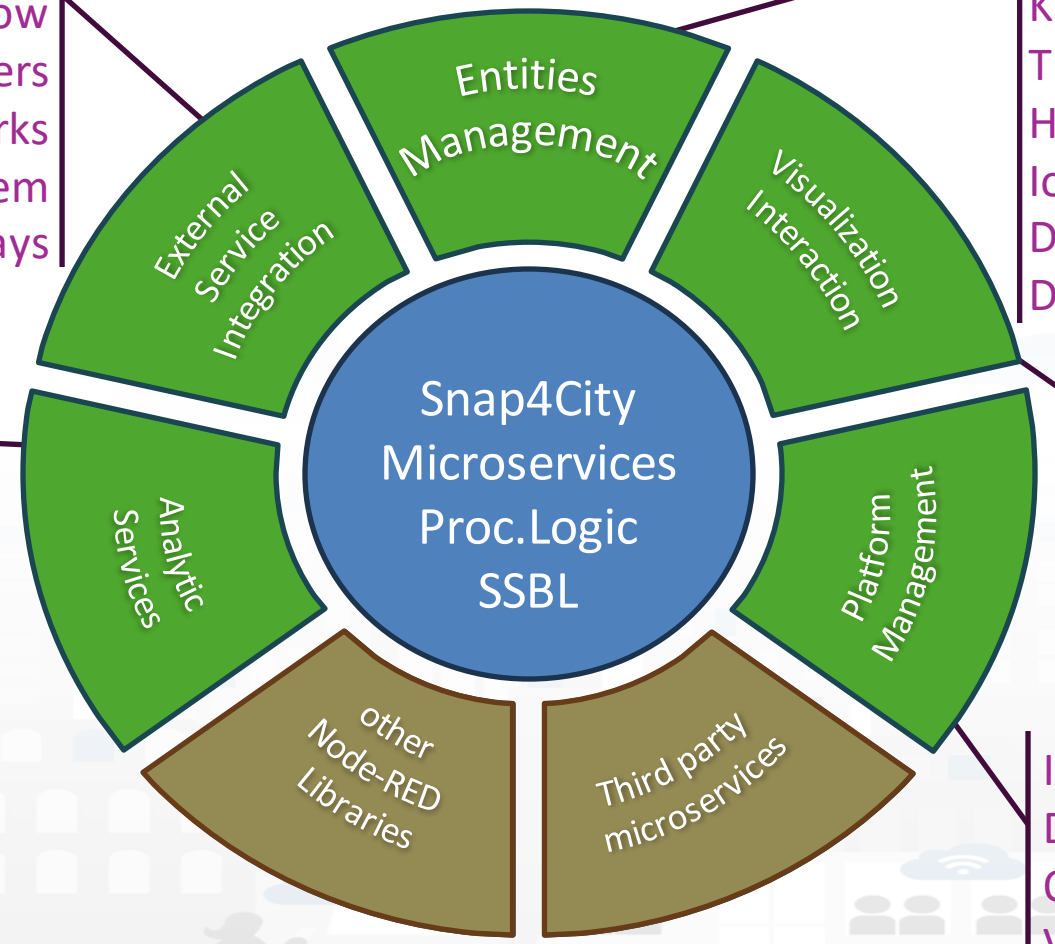
- **IoT App Visual Programming, no coding**
  - **Data transformation**
  - **Integration**
  - **Scripting Data Analytics**
  - **Data ingestion**
  - **Business logic**
- **MicroServices** data driven develop via visual language Node-RED





MicroServices Areas

> 60.000 downloads (up to 2024)



Open Data CKAN
Ticket Management, workflow
BIM Servers
Social Networks
Video Management system
Gateways

Data Load / Search / Retrieval
KPI, POI, GIS Data, Scenarios
Time Series, Public transport
High Level Types: heatmaps, ODM,…
IoT / Entity Discovery
Delegation Management
Data Mapping

Data Analytics
Statistic, Optimization
Simulation
Artificial Intelligence
What-if Analysis Support
Geo Utilities Support
Routing & Traffic Flow
MLOps support
Python support
R Studio Support

Dashboards
Widgets: Graphic Libraries
Interactive Widgets
Maps, 3D representations
Synoptics, External Content
Micro Web App

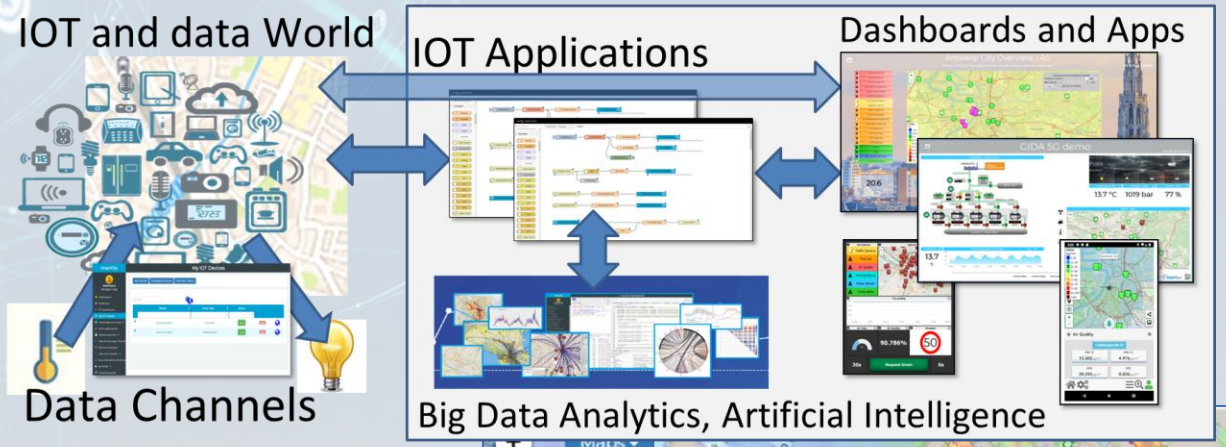
IoTApp Management
Data Logs, A&A, Security
Ownership Management
VPN remote access

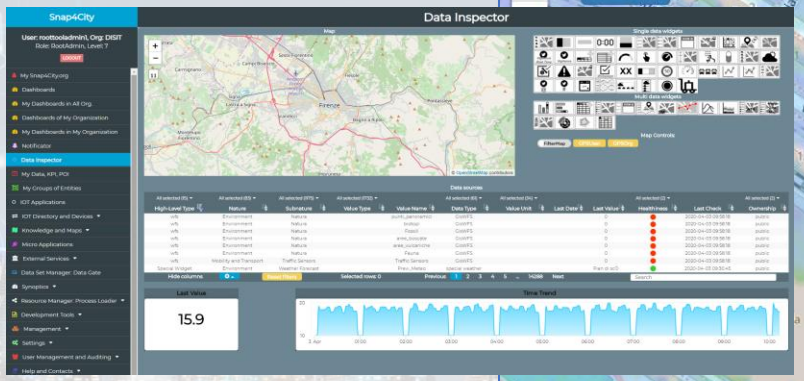
Node-RED

Solutions: reliable, secure and fast to realize

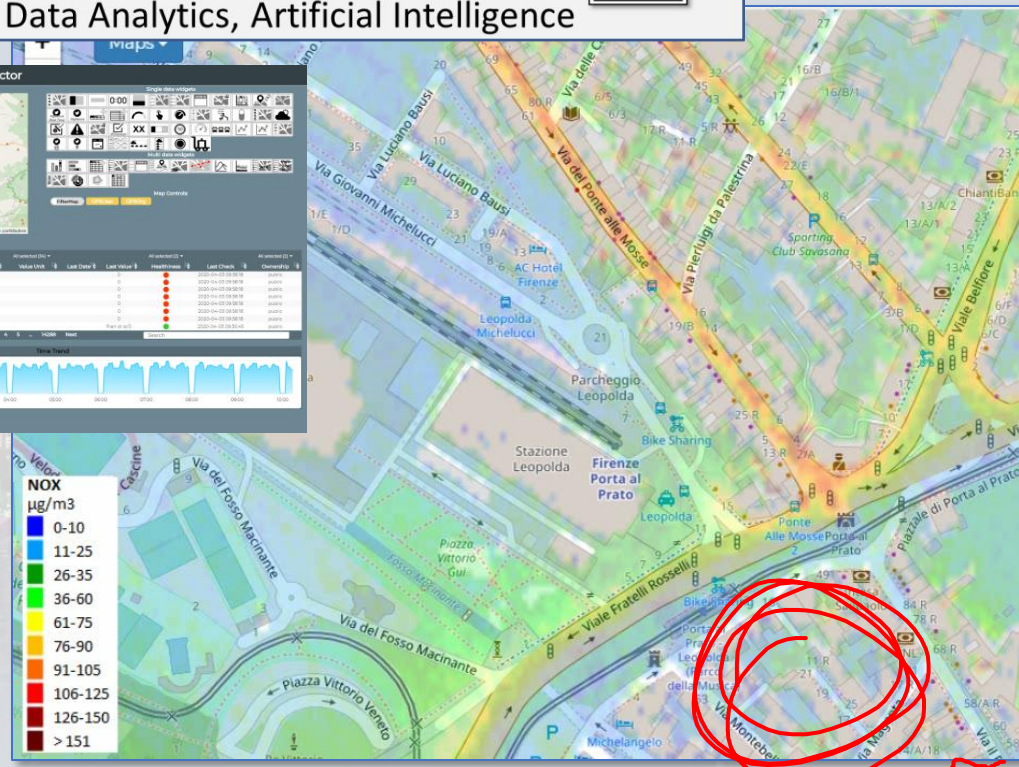
- **Via Snap4City tools**
  - **Dashboard Wizard**
  - **Dashboard Builder**
  - **Data/Visual Analytic**

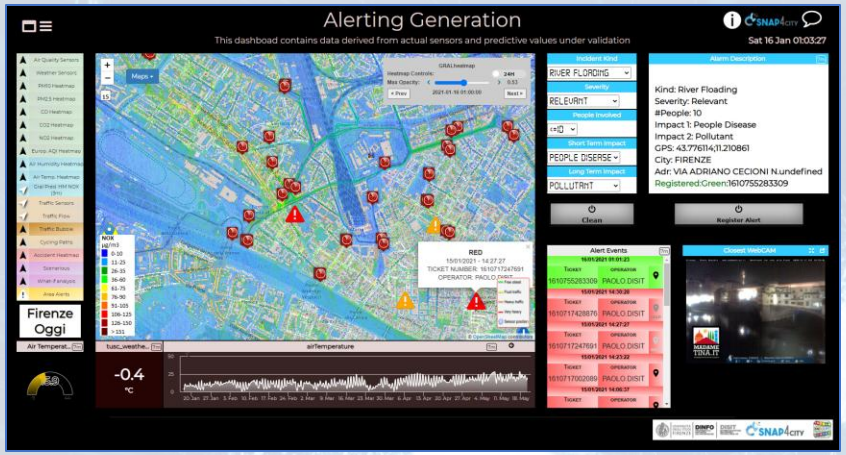
- **Smart Solutions results to be**
  - **Real time data drive**
  - **Secure end-to-end**
  - **GDPR compliant**
  - **Reliable, interoperable**
  - **Auditable, marketable**

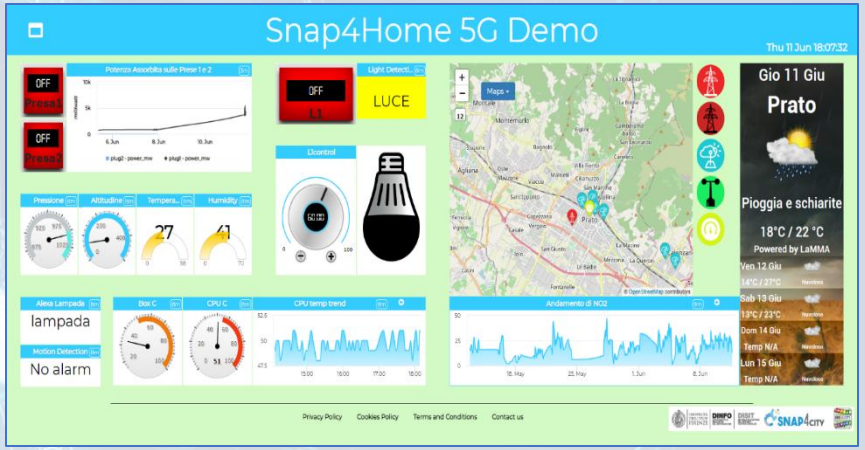


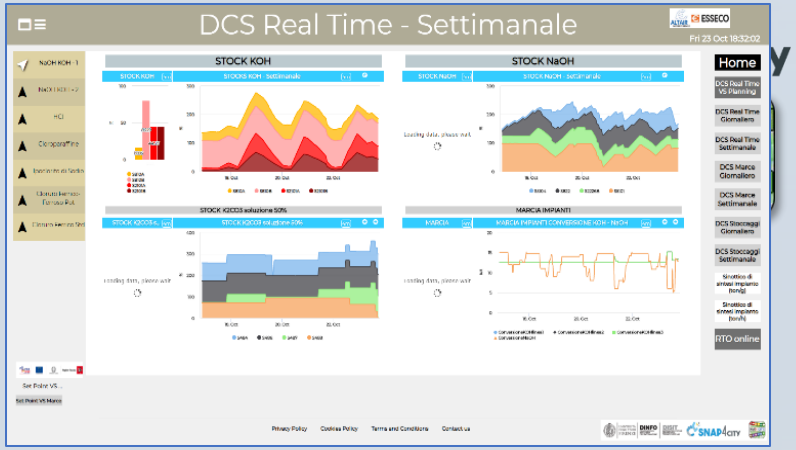


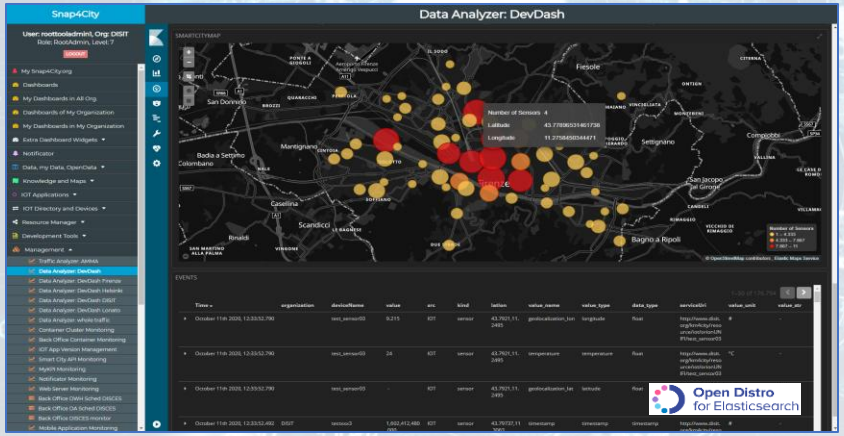


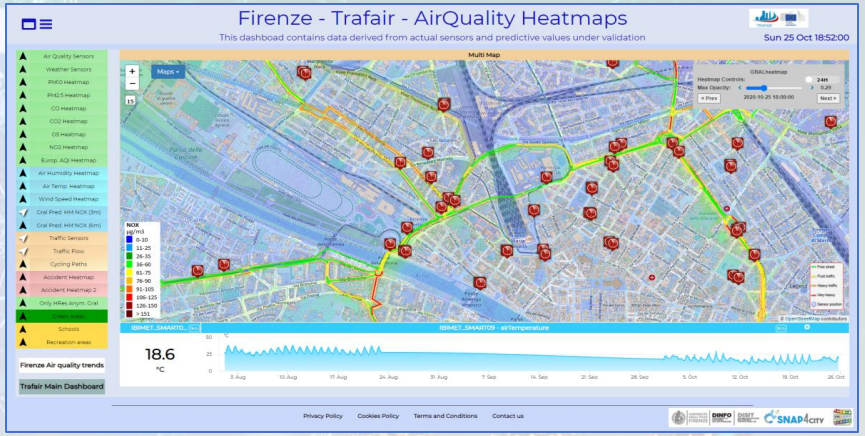


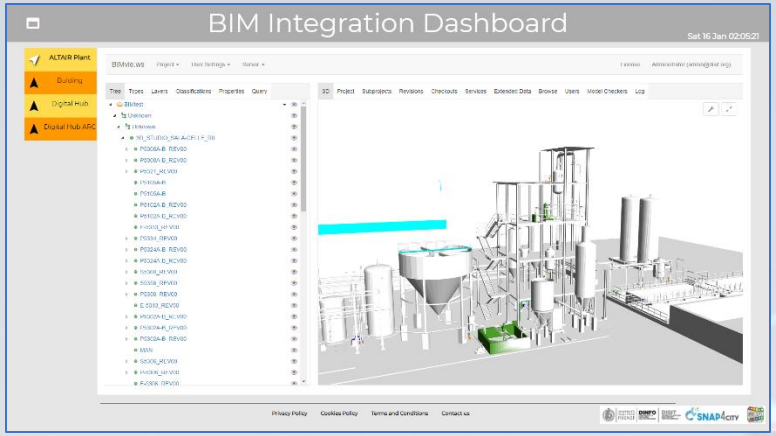

Alerting Generation
This dashboad contains data derived from actual sensors and predictive values under validation
Sat 16 Jan 01:03:27
Firenze Oggi
-0.4


Snap4Home 5G Demo
Thu 11 Jun 18:07:32
LUCE
lampada
No alarm
Gio 11 Giu
Prato
Pioggia e schiarite
18°C / 22 °C
Powered by LaMMA

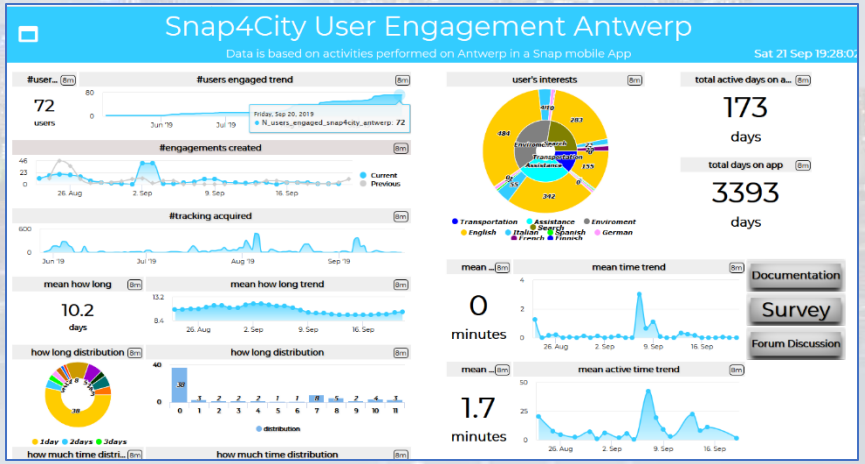

DCS Real Time - Settimanale
Fri 23 Oct 18:32:02
STOCK KOH
STOCK NaOH
Home

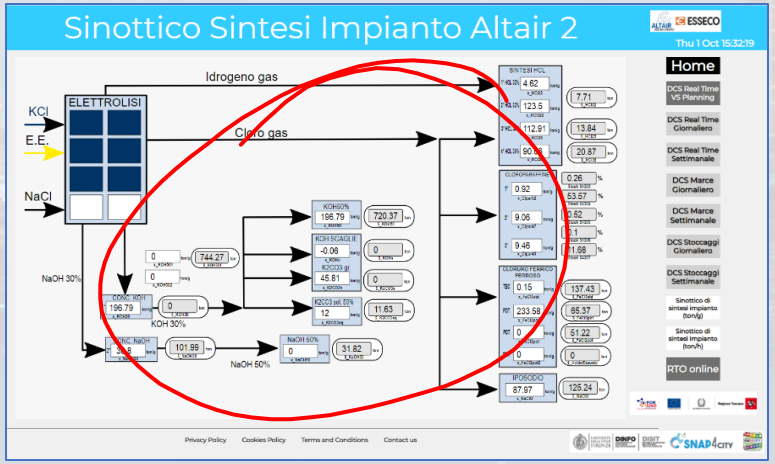

Data Analyzer: DevDash
Open Distro for Elasticsearch


Firenze - Trafair - AirQuality Heatmaps
This dashboad contains data derived from actual sensors and predictive values under validation
Sun 25 Oct 18:52:00
18.6


BIM Integration Dashboard
Sat 16 Jan 02:05:21

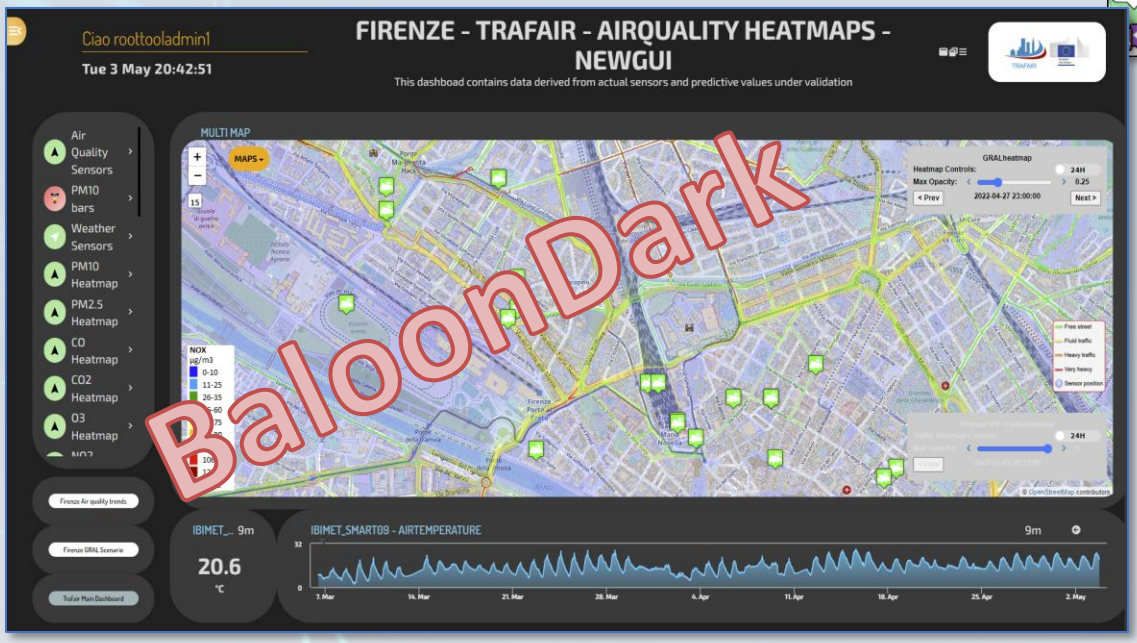

3D Multi Data Map - Digital Twin Global - Firenze
demonstrator
Sun 3 Apr 16:03:52
192

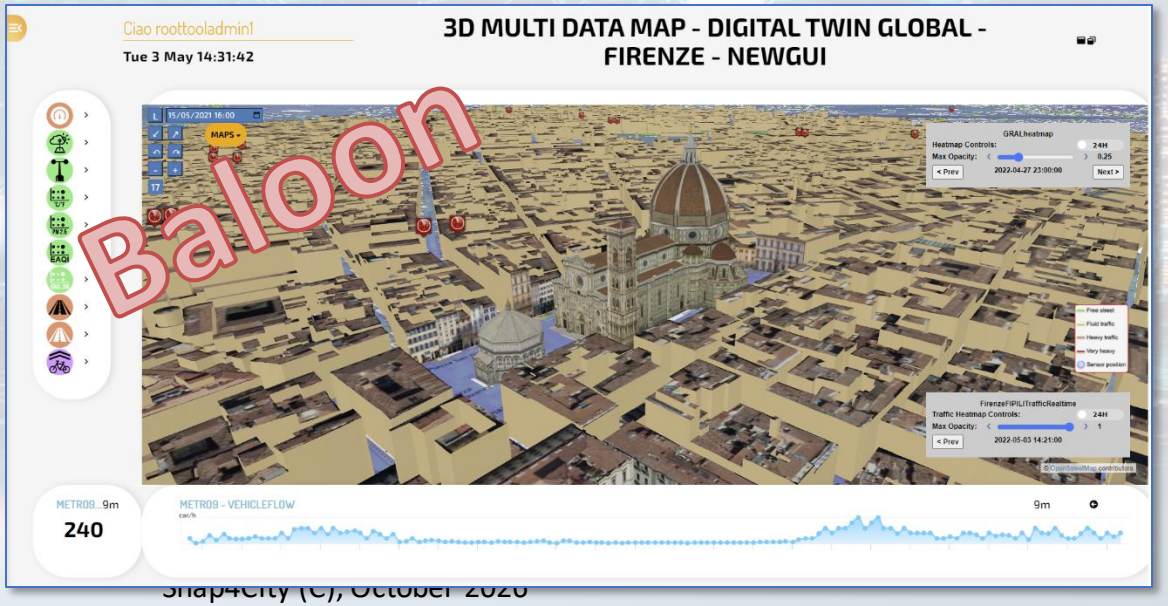

Snap4City User Engagement Antwerp
Data is based on activities performed on Antwerp in a Snap mobile App
Sat 21 Sep 19:28:07
72
users
173
days
3393
days
10.2
days
0
minutes
1.7
minutes
Documentation
Survey
Forum Discussion

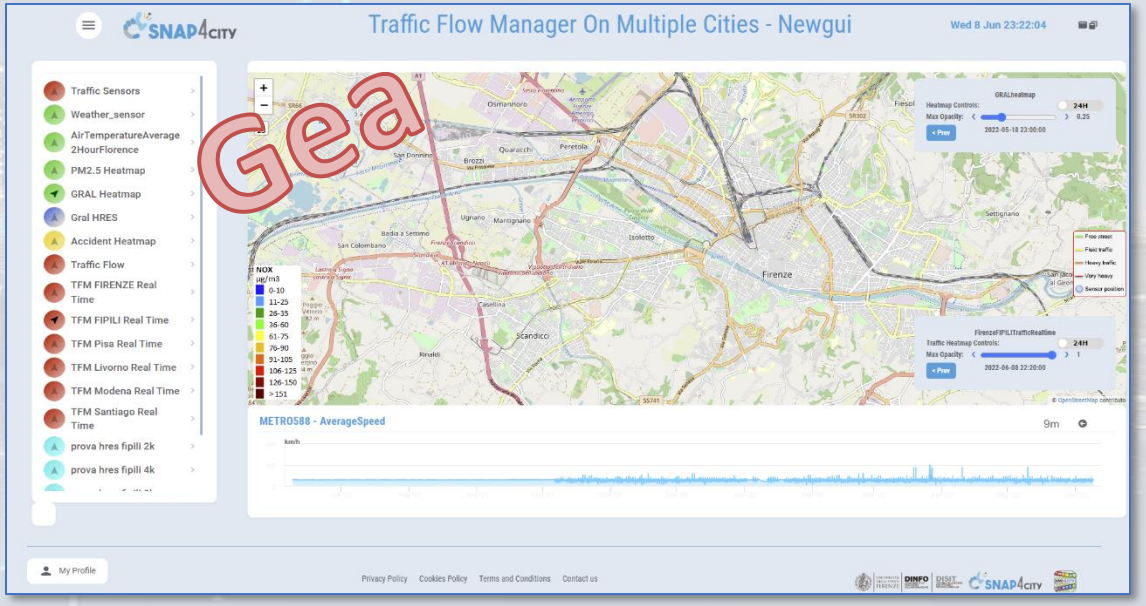

Sinottico Sintesi Impianto Altair 2
Thu 1 Oct 15:32:19
Idrogeno gas
Cloro gas
ELETTROLISI
KCl
E.E.
NaCl
NaOH 30%
KOH 30%
NaOH 50%
Home

Different Themes

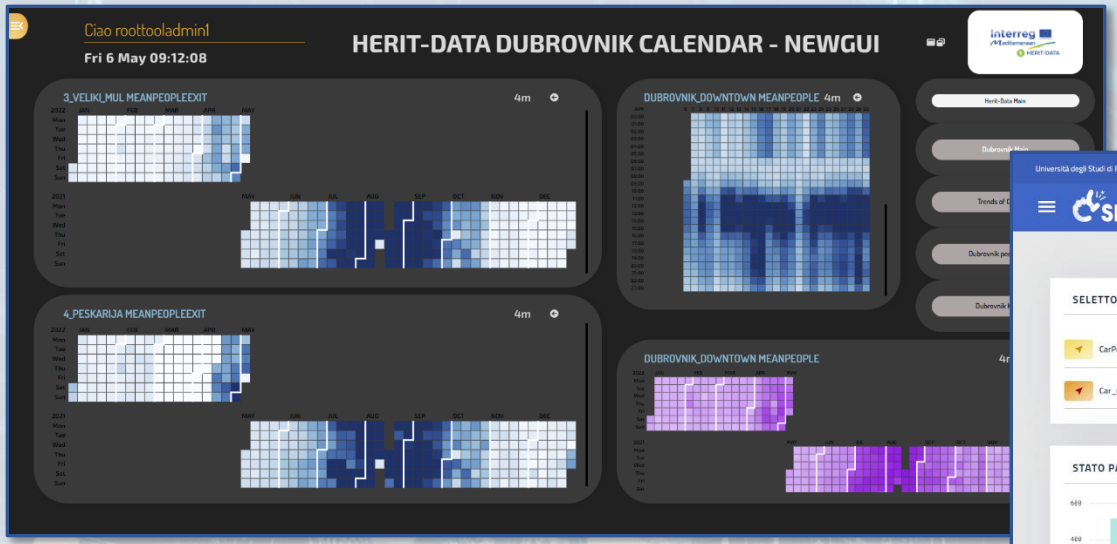


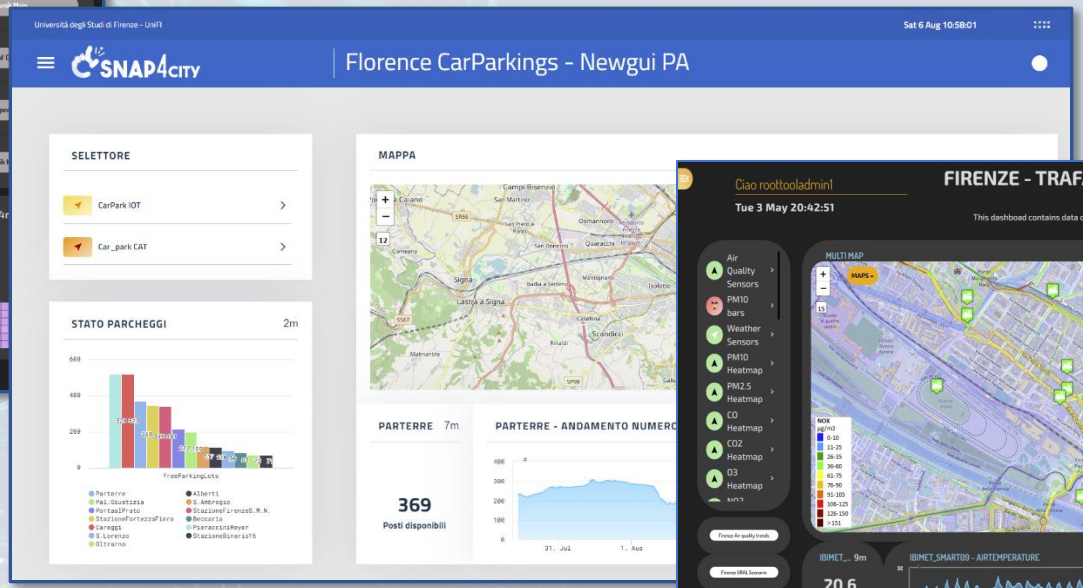


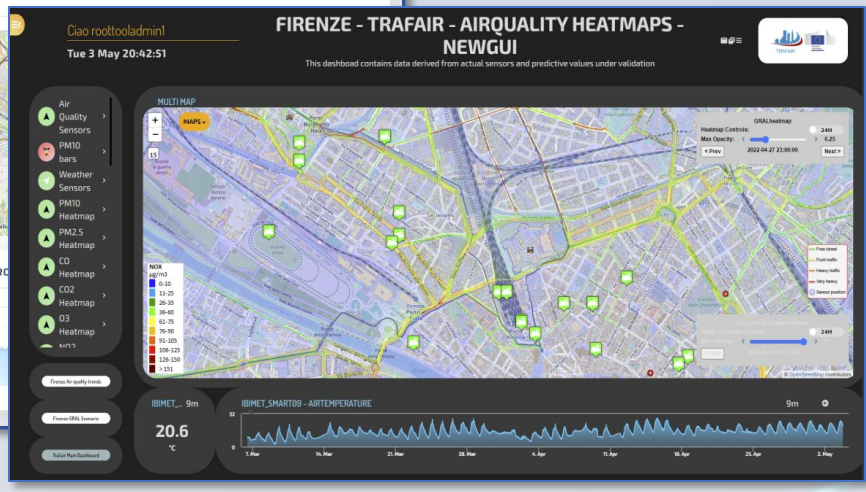


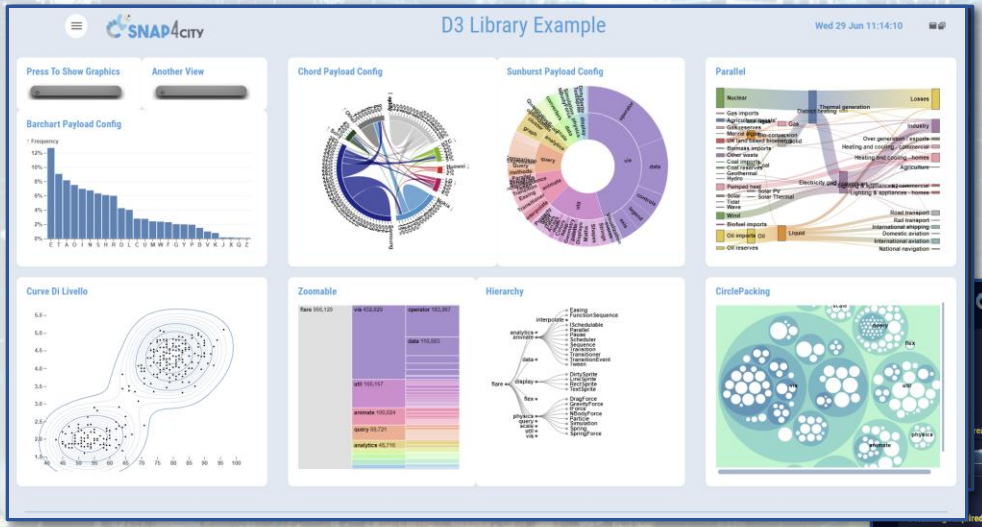


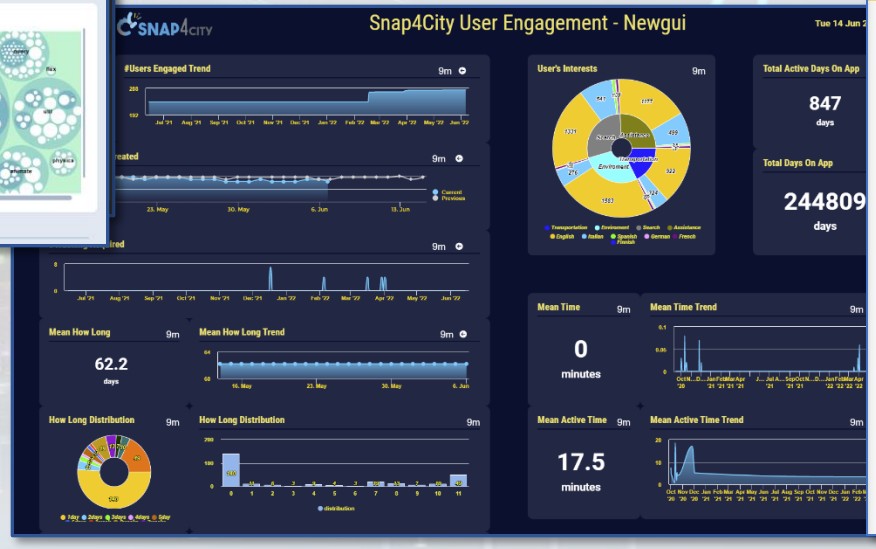
Different Themes

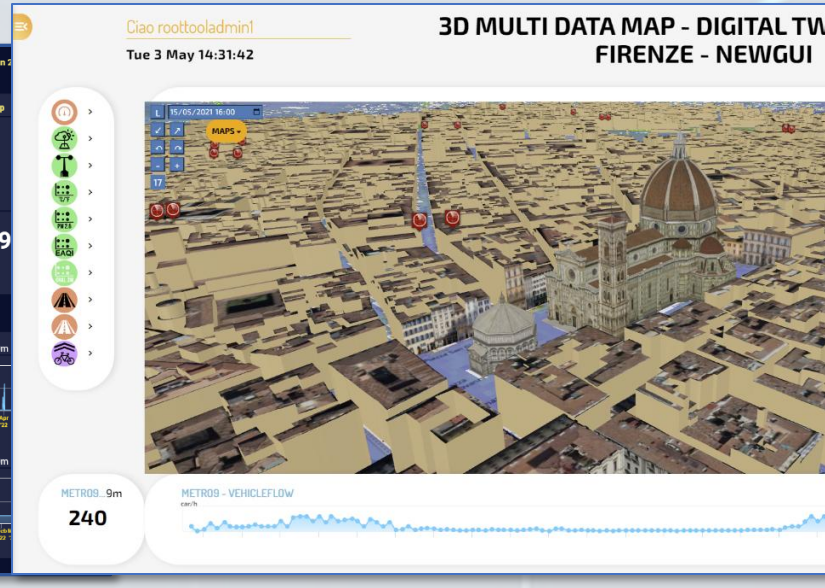






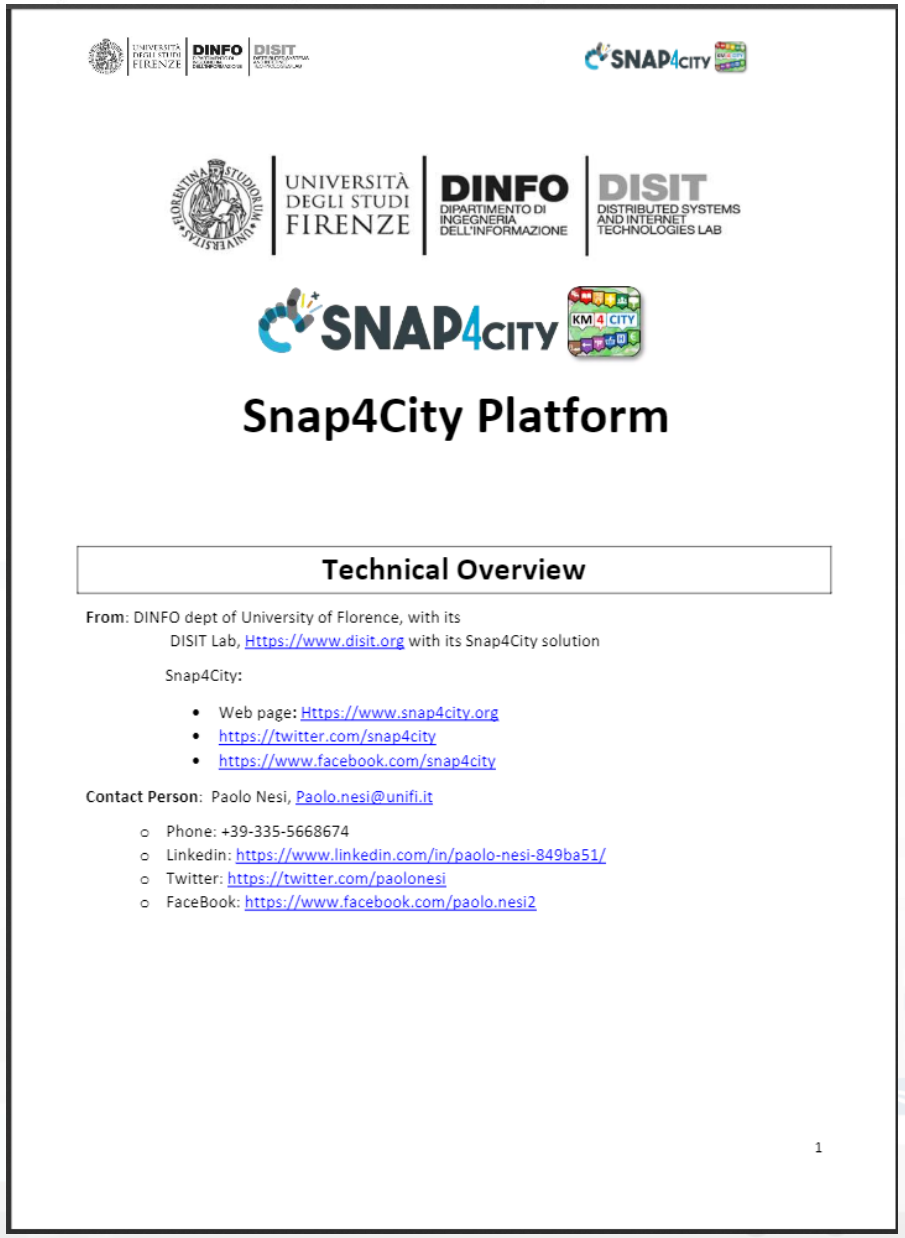






New styles/themes can be developed by specializing a few files from open source

https://www.snap4city.org/793



UNIVERSITÀ DEGLI STUDI FIRENZE | DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE | DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

SNAP4CITY

Snap4City Platform

Technical Overview

From: DINFO dept of University of Florence, with its
DISIT Lab, Https://www.disit.org with its Snap4City solution

Snap4City:

- Web page: Https://www.snap4city.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

Contact Person: Paolo Nesi, Paolo.nesi@unifi.it

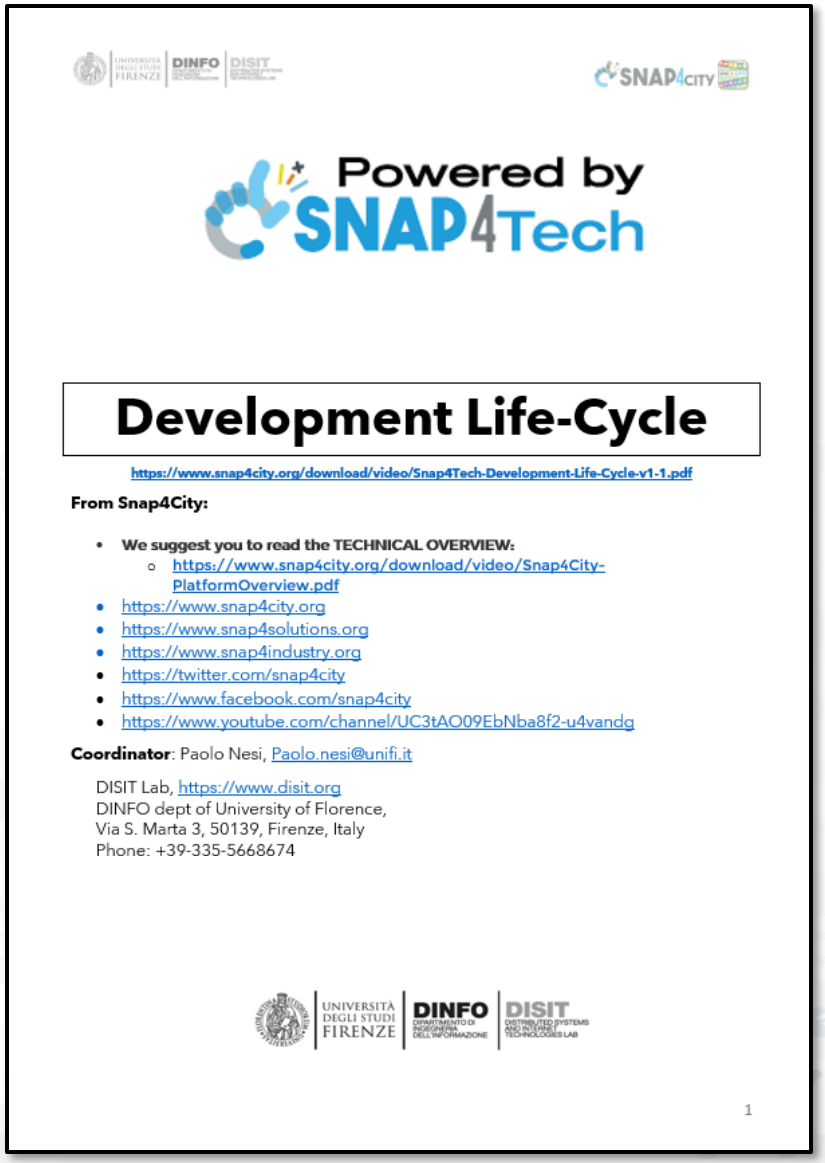
- Phone: +39-335-5668674
- Linkedin: https://www.linkedin.com/in/paolo-nesi-849ba51/
- Twitter: https://twitter.com/paolonesi
- FaceBook: https://www.facebook.com/paolo.nesi2

1

Tech Overview

- https://www.snap4city.org/drupal/sites/default/files/files/Snap4City-PlatformOverview.pdf

Development



Powered by SNAP4Tech

Development Life-Cycle

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle-v1-1.pdf

From Snap4City:

- **We suggest you to read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg

Coordinator: Paolo Nesi, Paolo.nesi@unifi.it

DISIT Lab, https://www.disit.org
DINFO dept of University of Florence,
Via S. Marta 3, 50139, Firenze, Italy
Phone: +39-335-5668674

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1

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf

Available AI Solutions on Snap4City

https://www.snap4city.org/997

More than 80 Available Solutions & 300 AI applic.

- **Mobility and Transport**
- **Waste Collection Optimisation**
- **Tourism Management**
- **City Users Behaviour**
- **Security and Safety**
- **Energy and Control**
- **Environment, Weather, Water**
- **High Level Decision Support Solutions**
  - **Asset management**
  - **Resilience and Risks Analysis**

03	**Artificial Intelligence:** ML, AI, DL, Fed.AI, LLM, DRL, Agentic AI, MCP tools, generative AI, … SnapAdvisor Copilot for developers, MLOps supp.
04	**Visual Intelligence:** visual programming for visual intelligence tools, Business intelligence, CSBL services, etc.
05	**Smart Applications:** dashboard builder, wizard, exploiting AI tools, Advisor Copilot, CSBL services, mobile Apps, multi services

https://www.snap4city.org/download/video/course/p4/

Data Analytics on Snap4City platform

Swagger







Ontology Schema



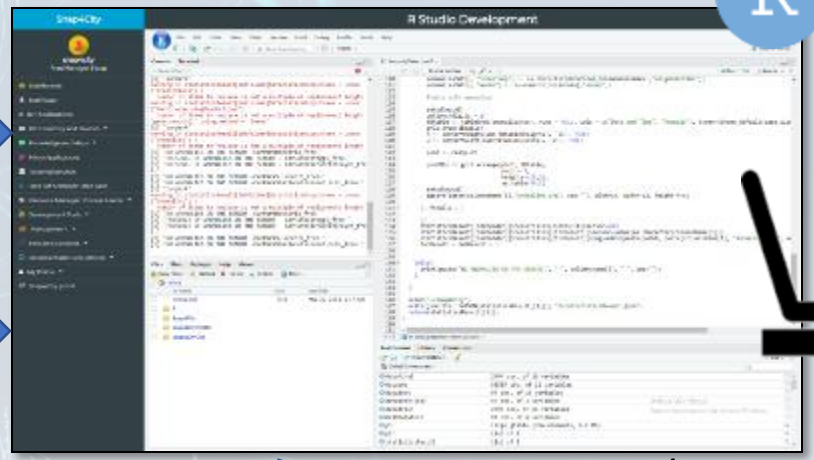
LOG.disit.org

Knowledge Base, Km4City

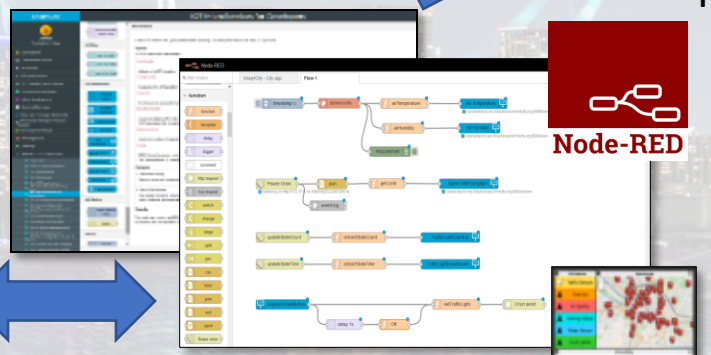


Big Data Store Facility

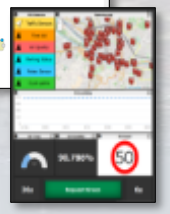
Smart City API from Knowledge Base and other tools



Creating MicroServices



Using them into IOT Applications



Saving / Sharing reusing



Resource Manager



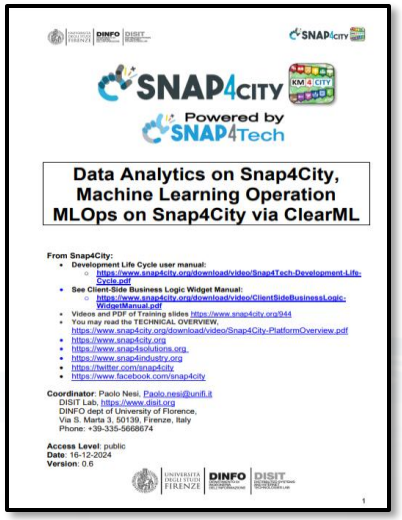
AI/ML developers, MLOps

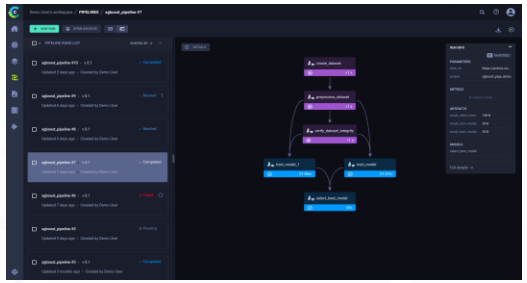
https://www.snap4city.org/download/video/Snap4City-MLOps-Manual.pdf

MLOps: AI, ML development
Automating training, hyperparam, optimisation
Any library and AI model, API, Agentic AI, MCP
Exploiting CPU/GPU clusters

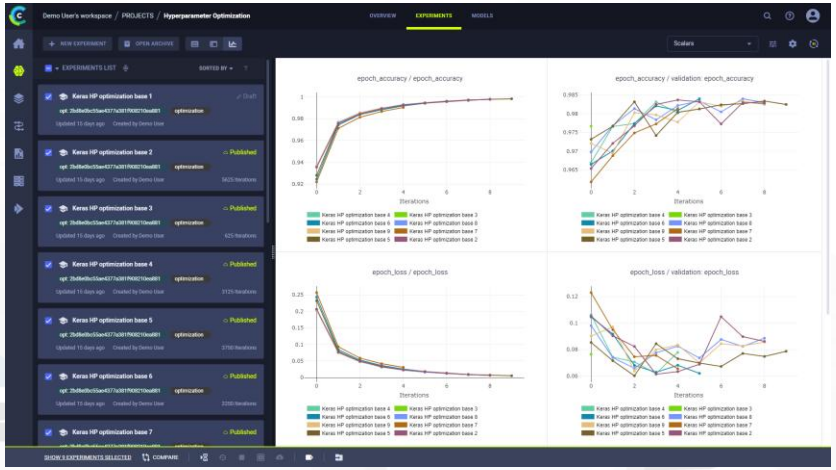
03	**Artificial Intelligence:** ML, AI, DL, Fed.AI, LLM, DRL, Agentic AI, MCP tools, generative AI, … SnapAdvisor Copilot for developers, MLOps supp.







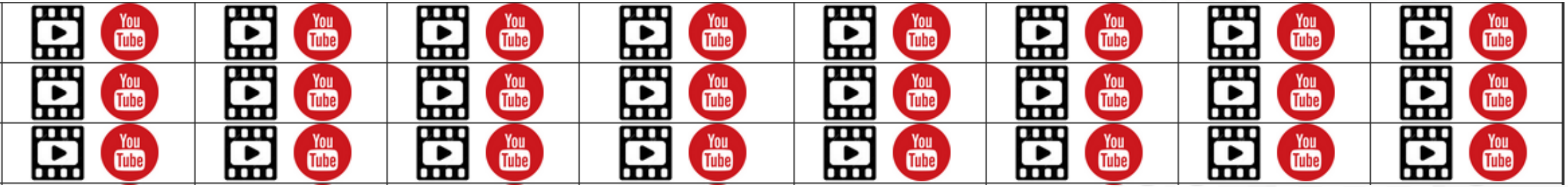




https://www.snap4city.org/944

On Line Training Material (free of charge)

1st part	2nd part	3rd part	4th part	5th part	6th part	7th part	8th
Overview	Dashboards	IOT App, IOT Network	Data Analytics	Data Ingestion processes	System and Deploy Install	Smart City API: Web & Mob. App	Design and Develop Smart Solutions
							
							



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DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

Interoperability

https://www.snap4City.org https://www.Km4City.org

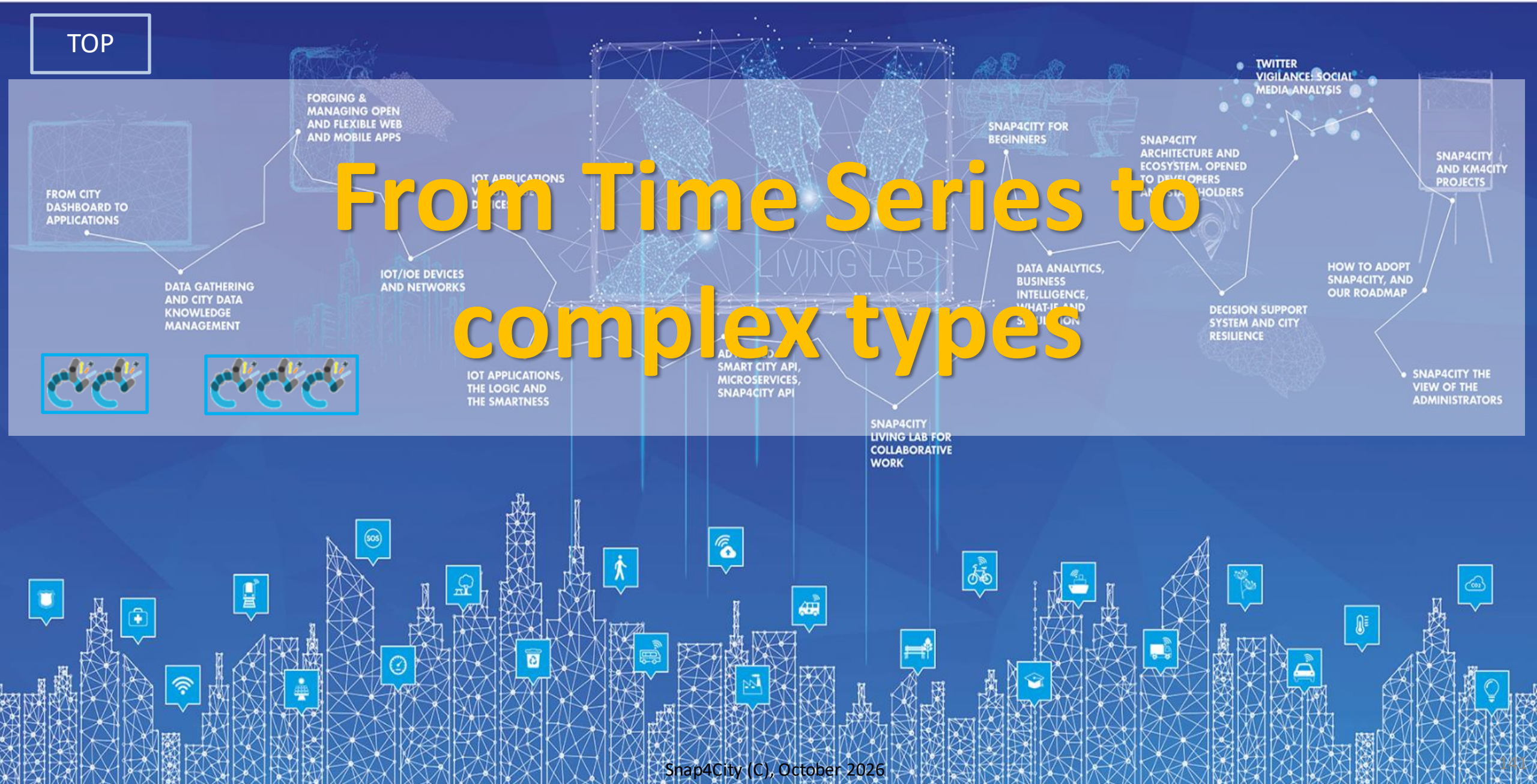
Parte: 4b (2024)



SOME RIGHTS RESERVED
BY NC ND

TOP

From Time Series to complex types



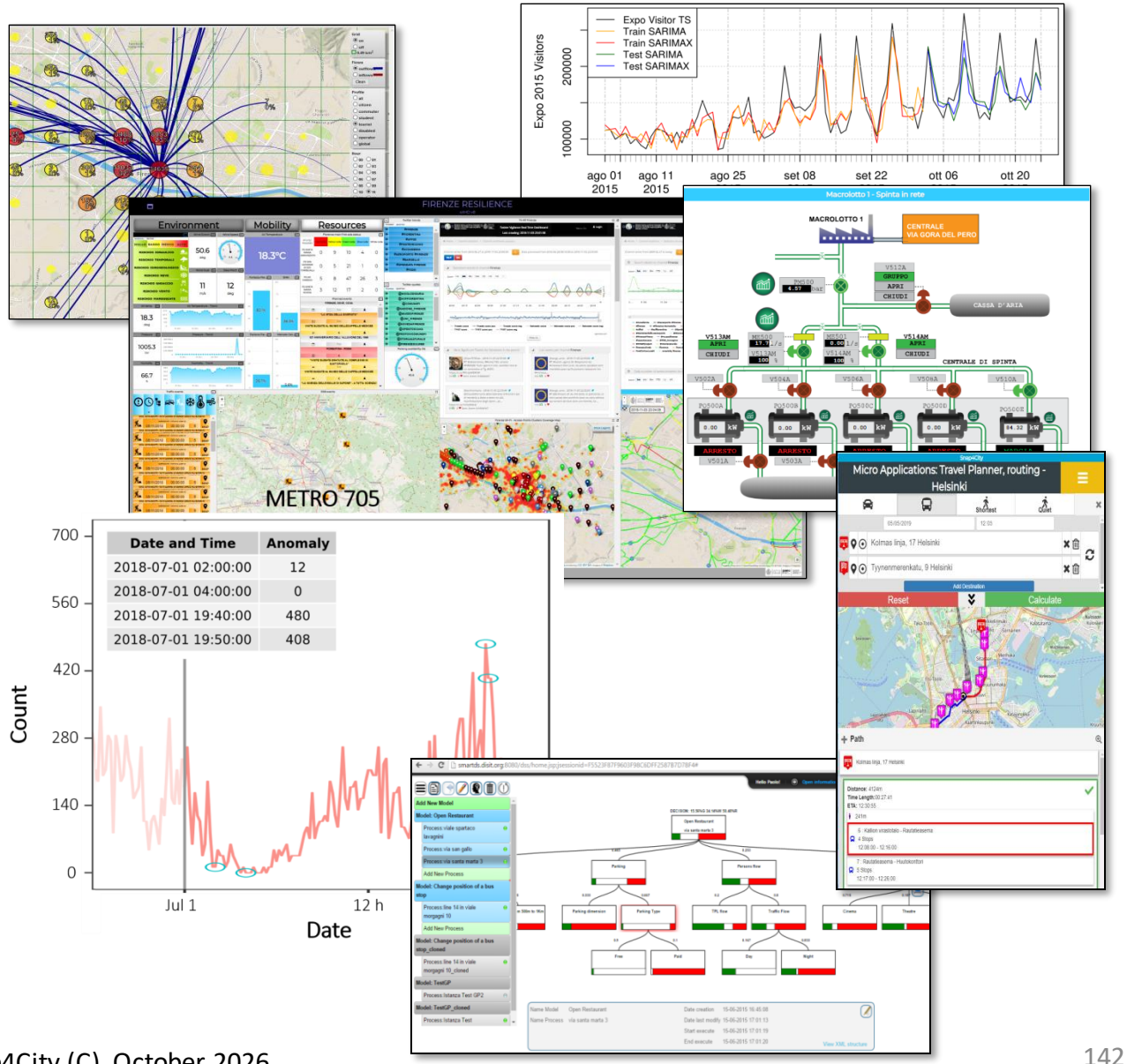
Decision Support, Act!

Control Room

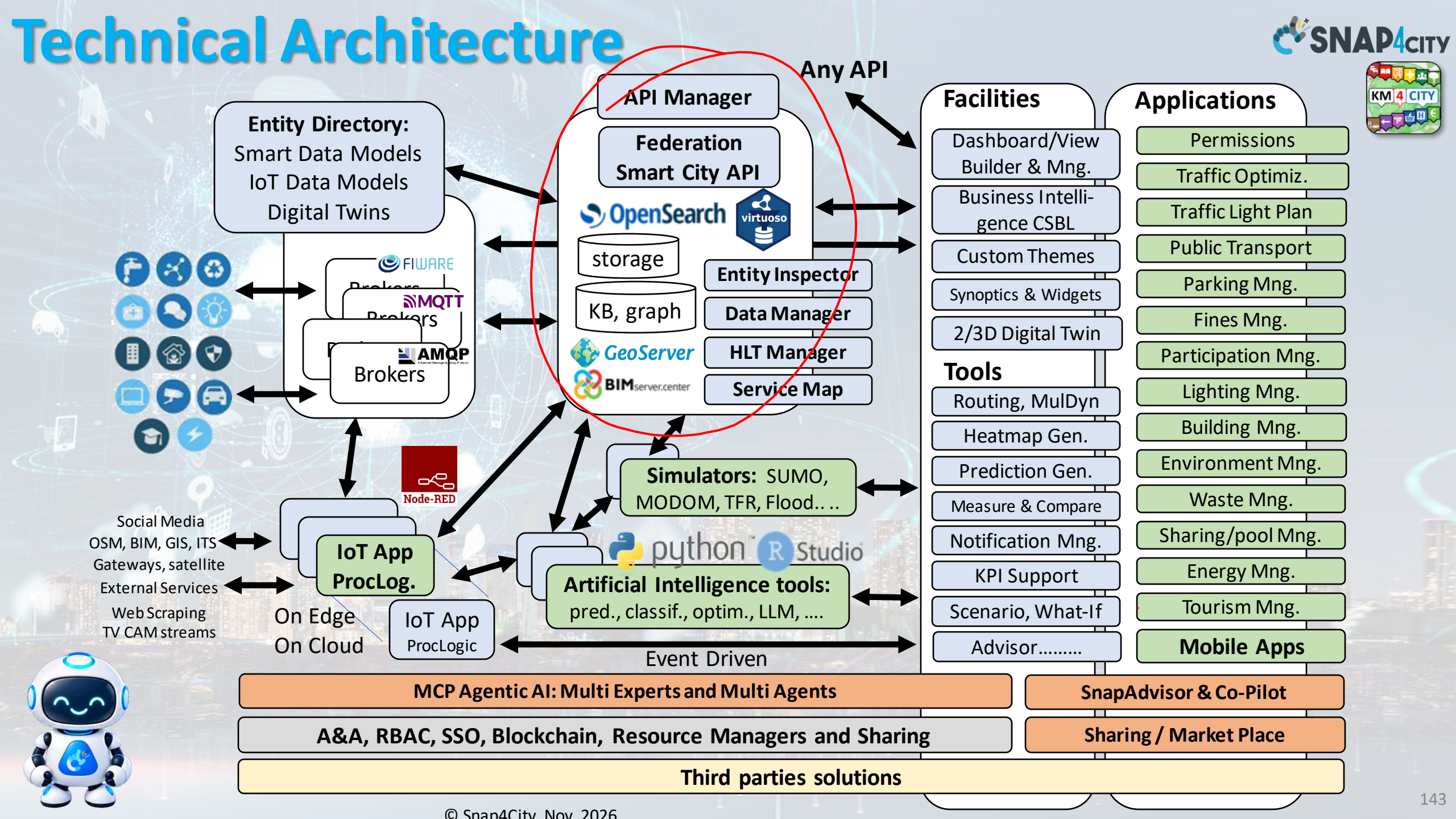
- Not only a collection of verticals

- **Exploiting analytics**: prediction, simulations, anomaly detection. ..
  - Big data approach to Data Analytics
- **Connecting Heterogeneous data** to defined strategies and alerting
- **Connected interactive dashboards** for different kind of decision makers: operators and majors
- **What-if Analysis taking into account multiple data sources, scenarios for hyp., KPI!!!!**
  - **simulation is needed**

From strategies to Actions

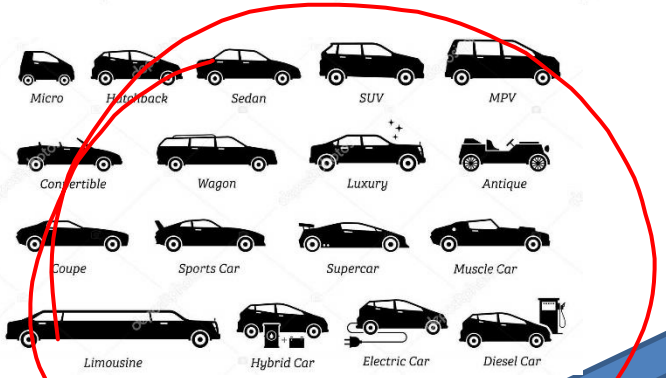


Technical Architecture



© Snap4City, Nov. 2026

Mobile Devices



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»



Sensor/Sensor-Actuator







Sensor Device

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

Sensors

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



- They are classified in terms of nature/subnature
- For Searching and showing on maps and dashboards **HLT of Sensors/Sensor-Actuator** can be:
  - **Sensor Device** name, for example: «mycoffemachine1», «CM23»
  - **Sensor/sensor-actuator** is a variable of a Sensor Device, for example: «Temperature»
- They do not have a model, while, in KB, have a reference process from which their real time data are collected from the field, from gateways, etc..

POI, Point of Interest

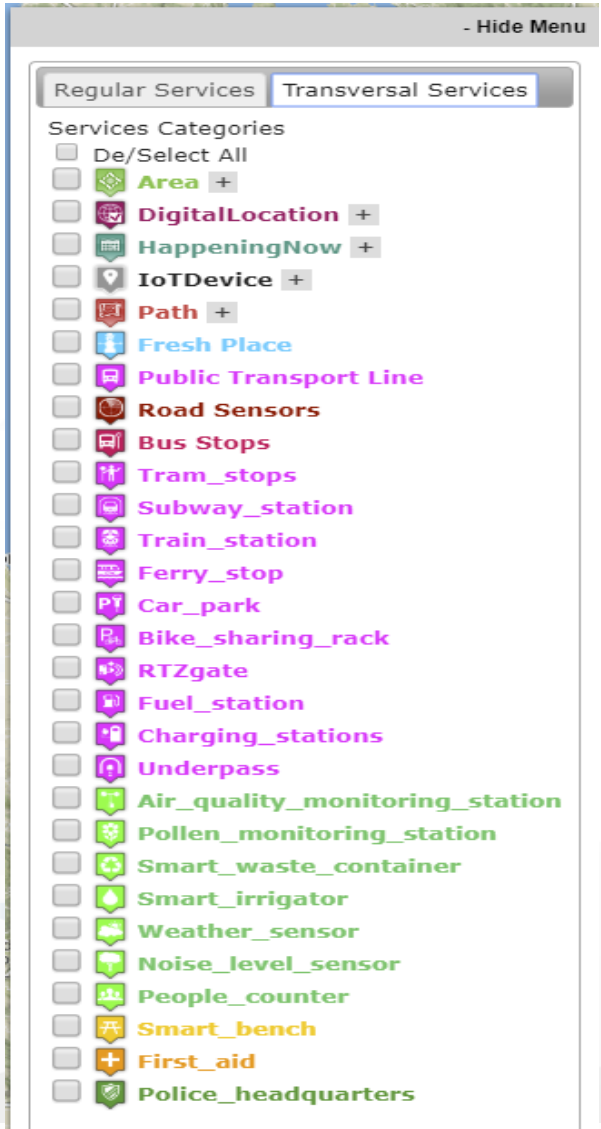
- They are
  - classified in terms of nature/subnature
  - relevant services with codified metadata to simplify the massive management of huge amount of POIs
  - mapped on Knowledge Base on **specific GPS location**
  - Do not move over time
  - represented as PIN
- Do not have Time Series for variable over time
- May sporadically change over time





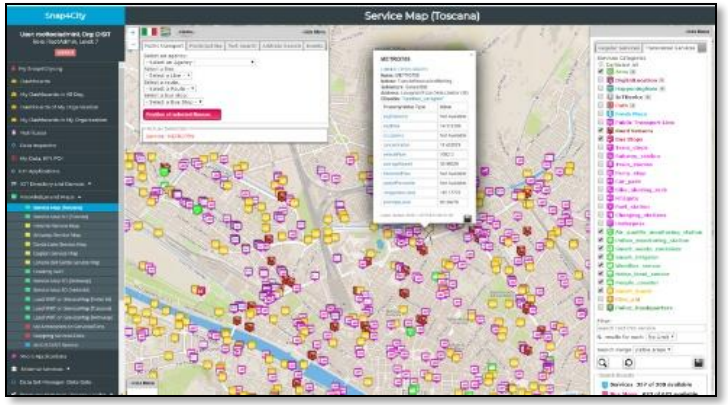
Access to Point of Interest information, POI

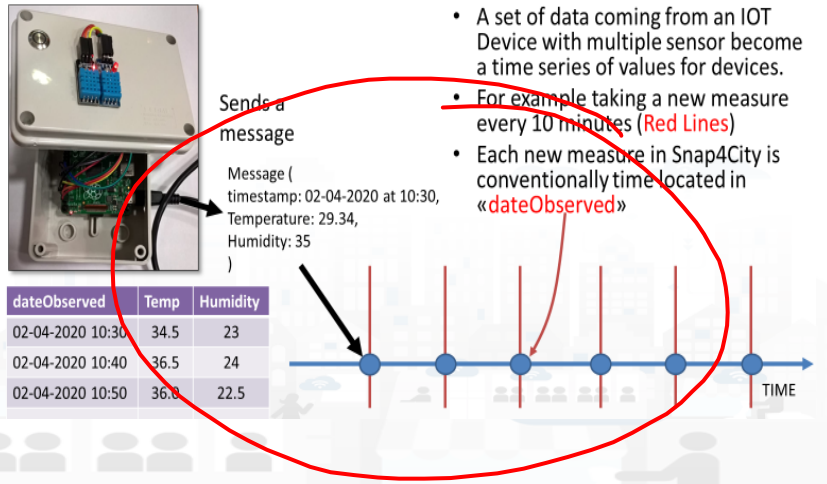
- **POI**: point of interest
- **type**: macro (nature) and subcategories (subnature)
- **Position**: GPS, address, telephone, fax, email, URL, …
- **Description**: textual, multilingual, with images, …
- **Link** to dbPedia, Linked Open Data
- **Links to other services**
- **Real time data if any:** sensors data, timeline, events, prices, opening time, rules of access, status of services, status of queue, etc..
- *See transversal services on ServiceMap*
  - *Regular and in test platform*



Data Ingestion Stragey

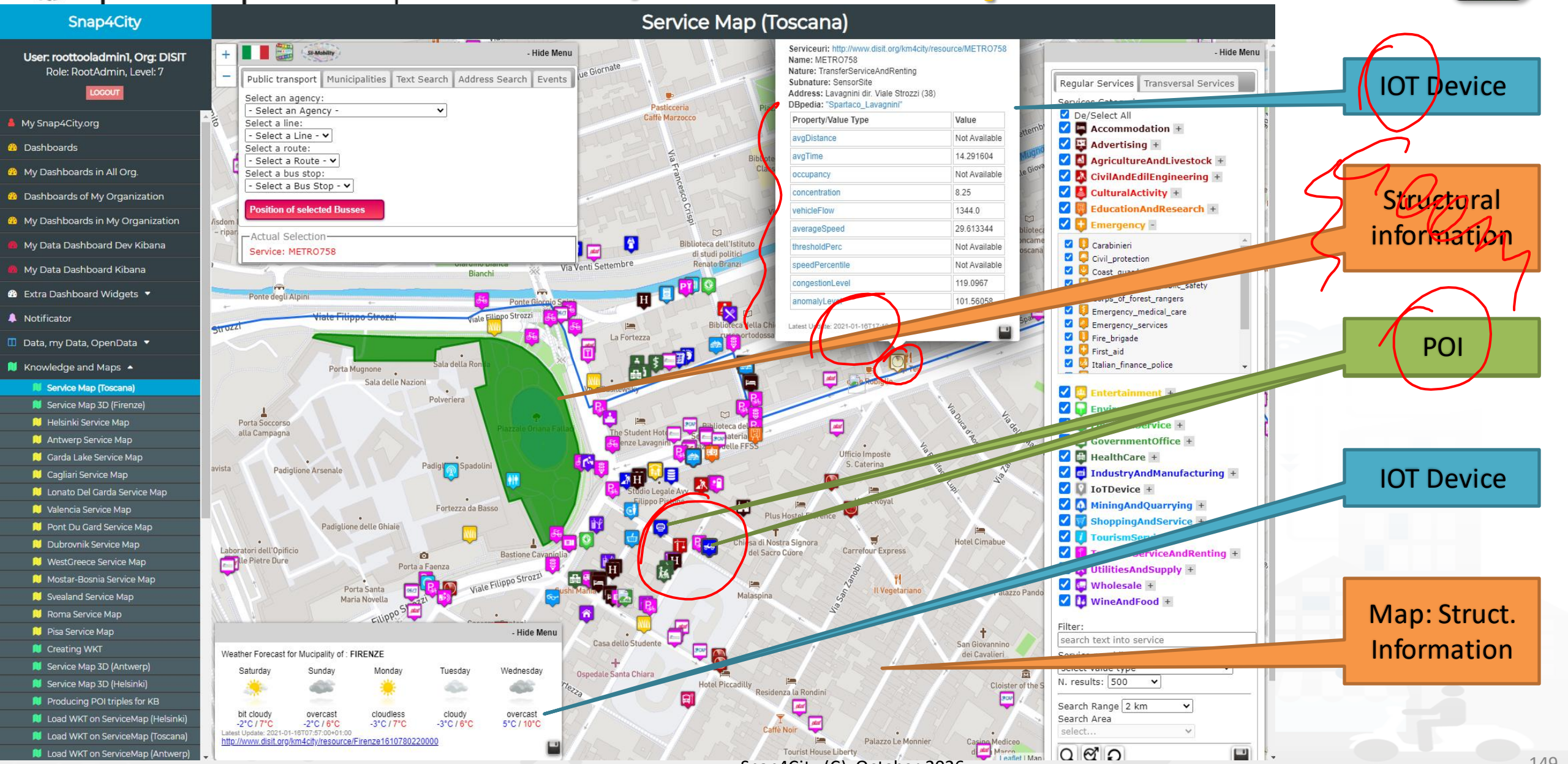
- **Structural Data**: Maps, orthomaps, geolocations, roads, etc.
  - Typically arrive as database, GIS data, etc.
  - **Suggested approaches**: IoT App, OSM → SM, ETL
- **POI (point of interest):** info point with geolocation as services, museums, restaurants, banks, email, urls, etc.
  - Typically arrive as: excel files, GIS data, etc.
  - **Suggested approaches**: POI Loader, IoT App, ETL
- **IoT Devices, Data Tables,… (Devices and Virtual Devices/KPI), including**
  - Description, including geolocations, etc.
  - Time Series: measures that change over time,
  - They can also move → **IoT Device Mobile, Data Tables**
  - Typically arrive as:
    - description and real time values or additional values
    - Excel files with description and data all together
  - **Suggested approach**: Data Table Loader, IoT App, Brokers, ETL
    - IoT Brokers also send data in real time





ETL: deprecated approach in V2

KB, ServiceMap

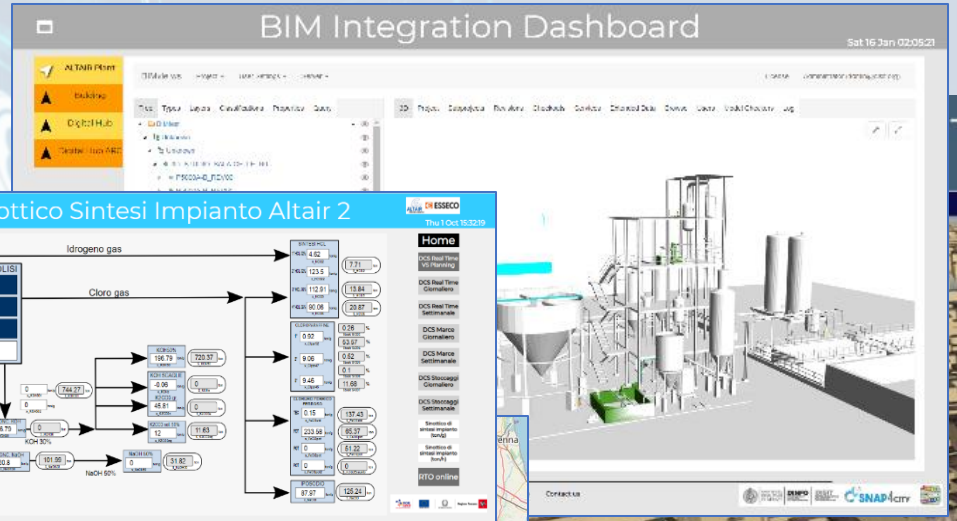


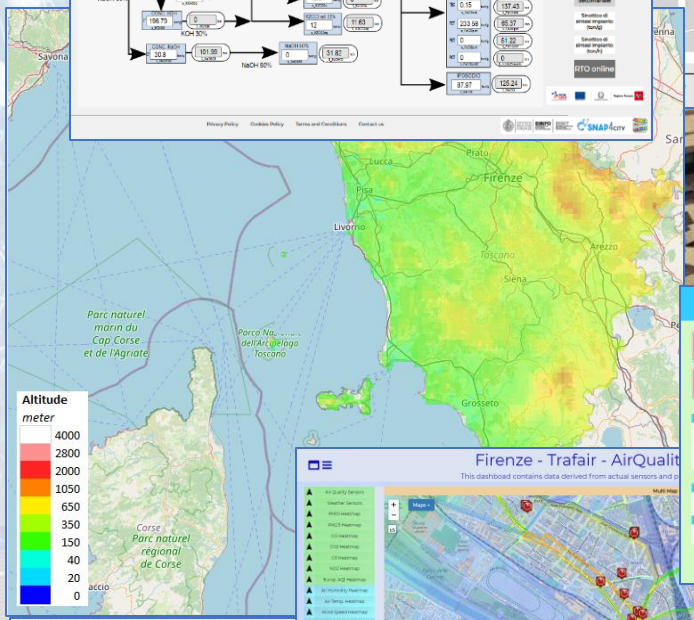
High Level Types

Snap4City (C), October 2026

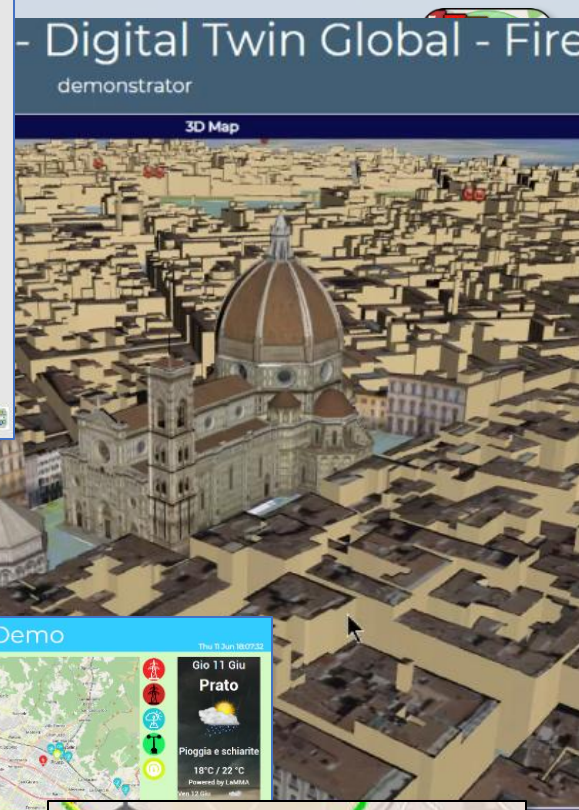
- POI, IOT Devices, shapes,..
  - ***FIWARE Smart Data Models,***
  - ***IoT Device Models***
  - ***Any custom data model***
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, any kind..
- traffic flow, typical trends, ..
- Vector fields + heatmaps, ..
- trajectories, events, workflow, ..
- 3D Models, BIM, Digital Twins, ..
- OD Matrices of several kinds, ..
- Dynamic icons/pins, ..
- Synoptics, animations, ..
- KPI, personal KPI,..
- social media data, TV Stream,
- routing, multimodal, constraints, ..
- scenarios, ….
- etc.



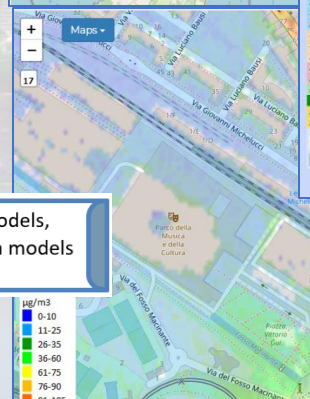


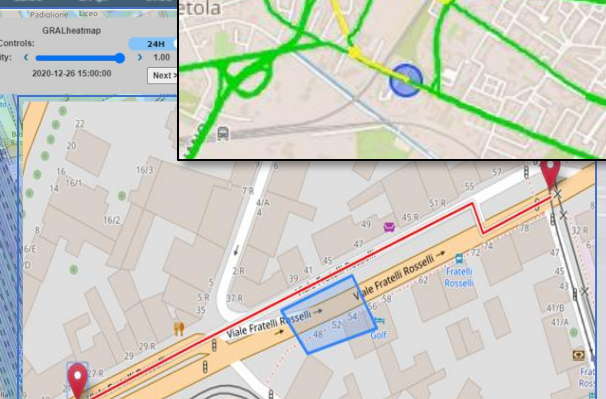












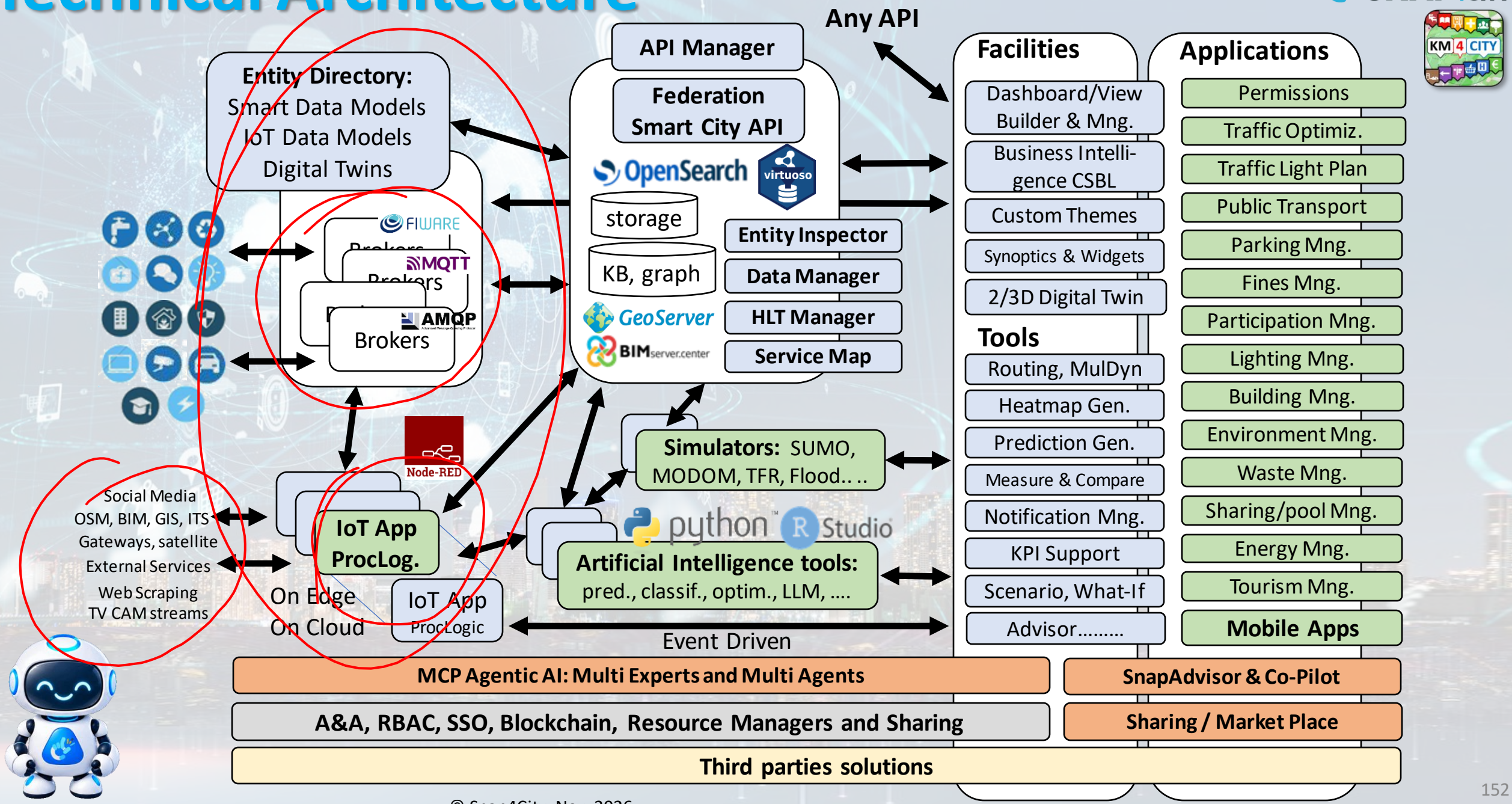


02	**Data Model:** standard and custom data models, dictionary, ontology; Data Spaces, MDS; data models FIWARE, etc.



Interoperability of Snap4City Platform

Technical Architecture



© Snap4City Nov 2026

Standards and Interoperability

Compliant with:

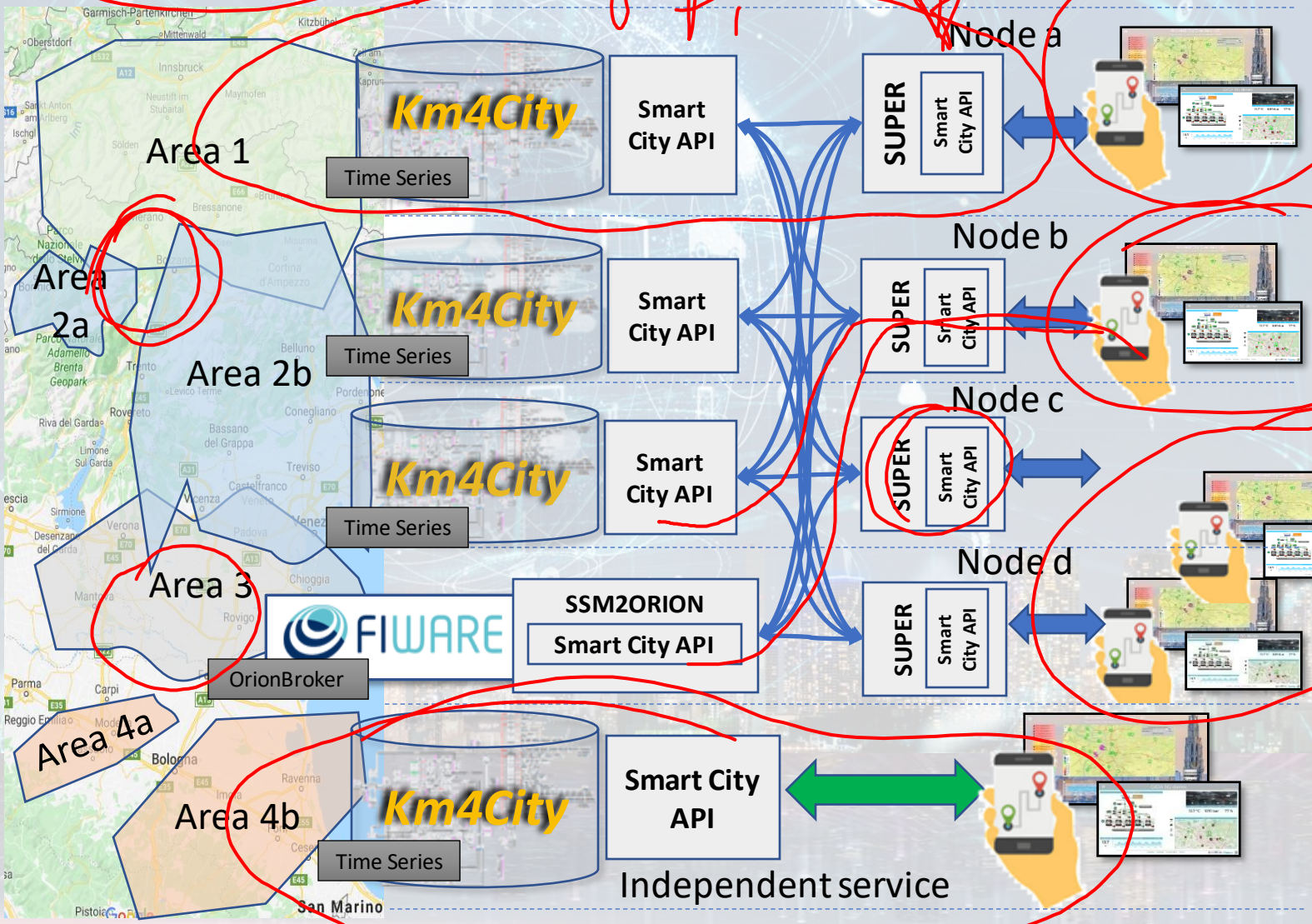
- **IoT:** NGSI V2/LD, LoRa, LoRaWan, MQTT, AMQP, COAP, OneM2M, TheThingsNetwork, SigFOX, Libelium, IBIMET/IBE, Enocean, Zigbee, DALI, ISEMC, Alexa, Sonoff, HUE Philips, Tplink, BACnet, TALQ, Protocol Buffer, KNX, OBD2, Proximus, ..
- **IoT model:** FIWARE Smart Data Model, Snap4City IoT Device Models
- **General**: HTTP, HTTPS, TLS, Rest Call, SNMP, TCP, UDP, SOAP, WSDL, FTP, FTPS, WebSocket, WebSocket Secure, GML, WFS, WMS, WCS, RTSP, ONVIF, AXIS TVCam, CISCO Meraki, OSM, Copernicus, The Weather Channel, Open Weather, OLAP, VMS Milestone, TIM, HERE, OGC, ….
- **Formats**: JSON, GeoJSON, XML, CSV, GeoTIFF, OWL, WKT, KML, SHP, db, XLS, XLSX, TXT, HTML, CSS, SVG, IFC, XPDL, OSM, Enfuser FMI, Lidar, glTF, GLB, DTM, GDAL, Satellite, D3 JSON, …
- **Database**: Open Search, MySQL, Mongo, HBASE, SOLR, SPARQL, ODBC, JDBC, Elastic Search, Phoenix, PostGres, MS Azure, ..
- **Industry**: OPC/OPC-UA, OLAP, ModBUS, RS485, RS232,..
- **Mobility**: DATEX, GTFS, Transmodel, ETSI, NeTEx, ..
- **Social**:Twitter, FaceBook, Telegram, ..
- **Events**: SMS, EMAIL, CAP, RSS Feed, ..
- **OS**: Linux, Windows, Android, Raspberry Pi, Local File System, AXIS. ESP32. etc.

https://www.snap4city.org/65

01	**Interoperability:** any format, any protocol, any API, visual programming node-red, Python, brokers, etc. Server Sides Business Models, ETL, ELT, ..

Federation of Smart City Services

Knowledge Base
Semantic Reasoners



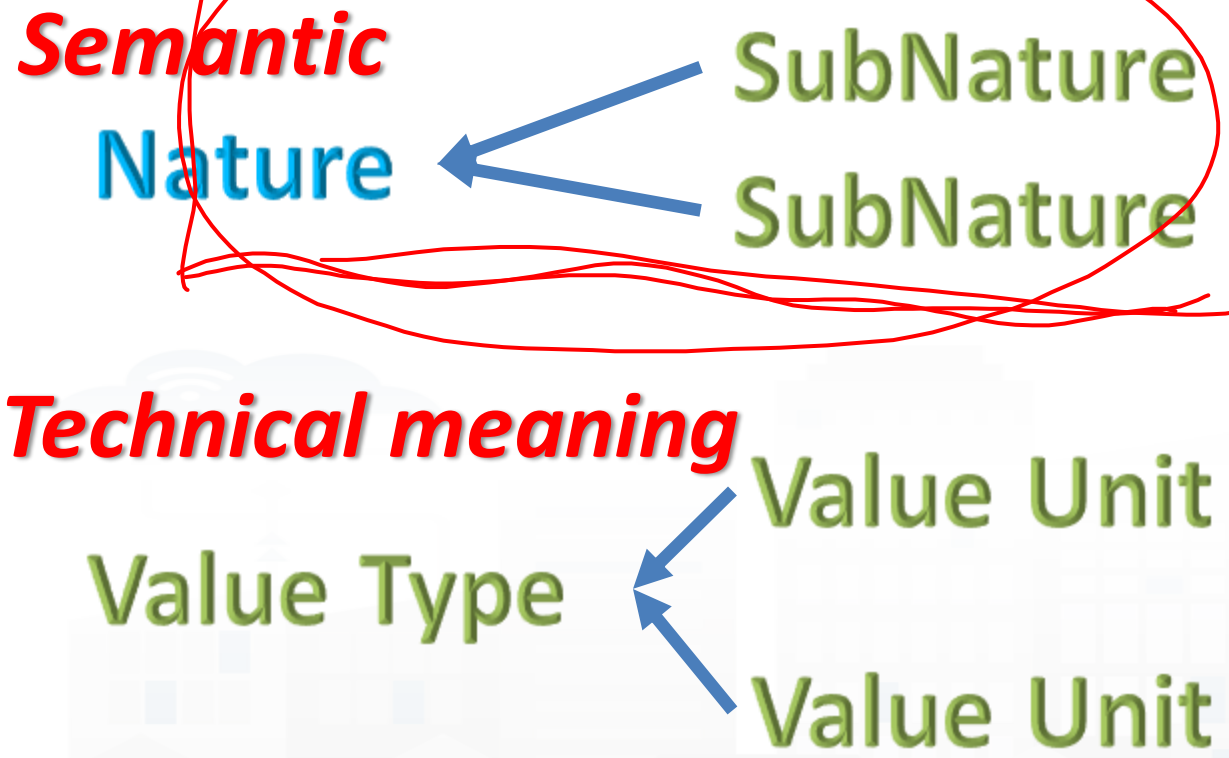
- Km4City **Semantic Reasoner**
- **ServiceMap** interoperability
- **Seamless for multiple Mobile Apps**
- **Smart City API**
- **Super**:
  - distributed access and sharing services
  - Each city control its own data
  - Final user can pass from one city / area to another in seamless manner: without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

Dictionary for Data Fields

Semantics and Technical Meaning



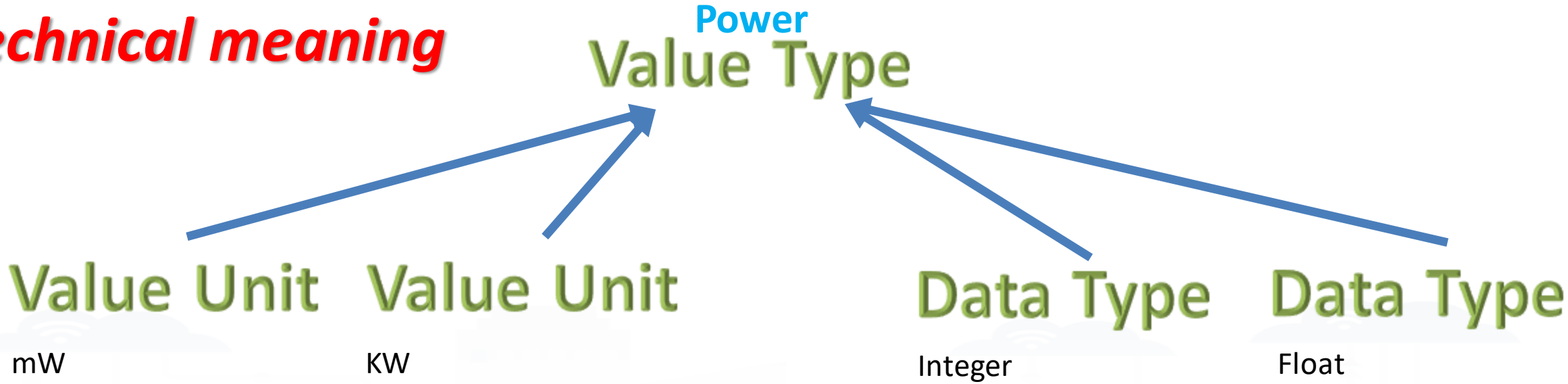
Unified Data and Services Model/Classification



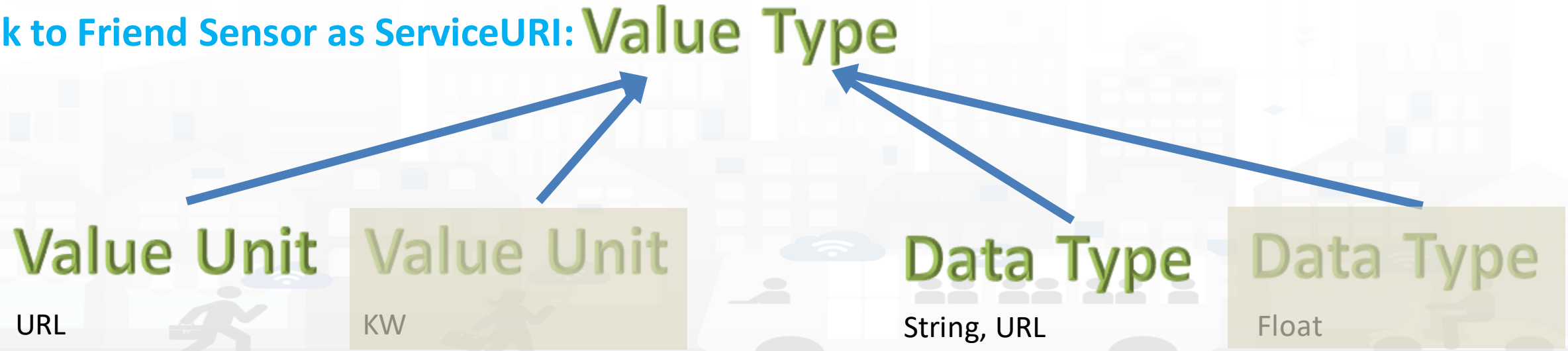
- Exists a Dictionary for the 4 categories
- They are related each other and not all values are possible
- Right setting lead to right rendering on graphs and automated combinations and processing
- The Disctionary is used by many tools

For example

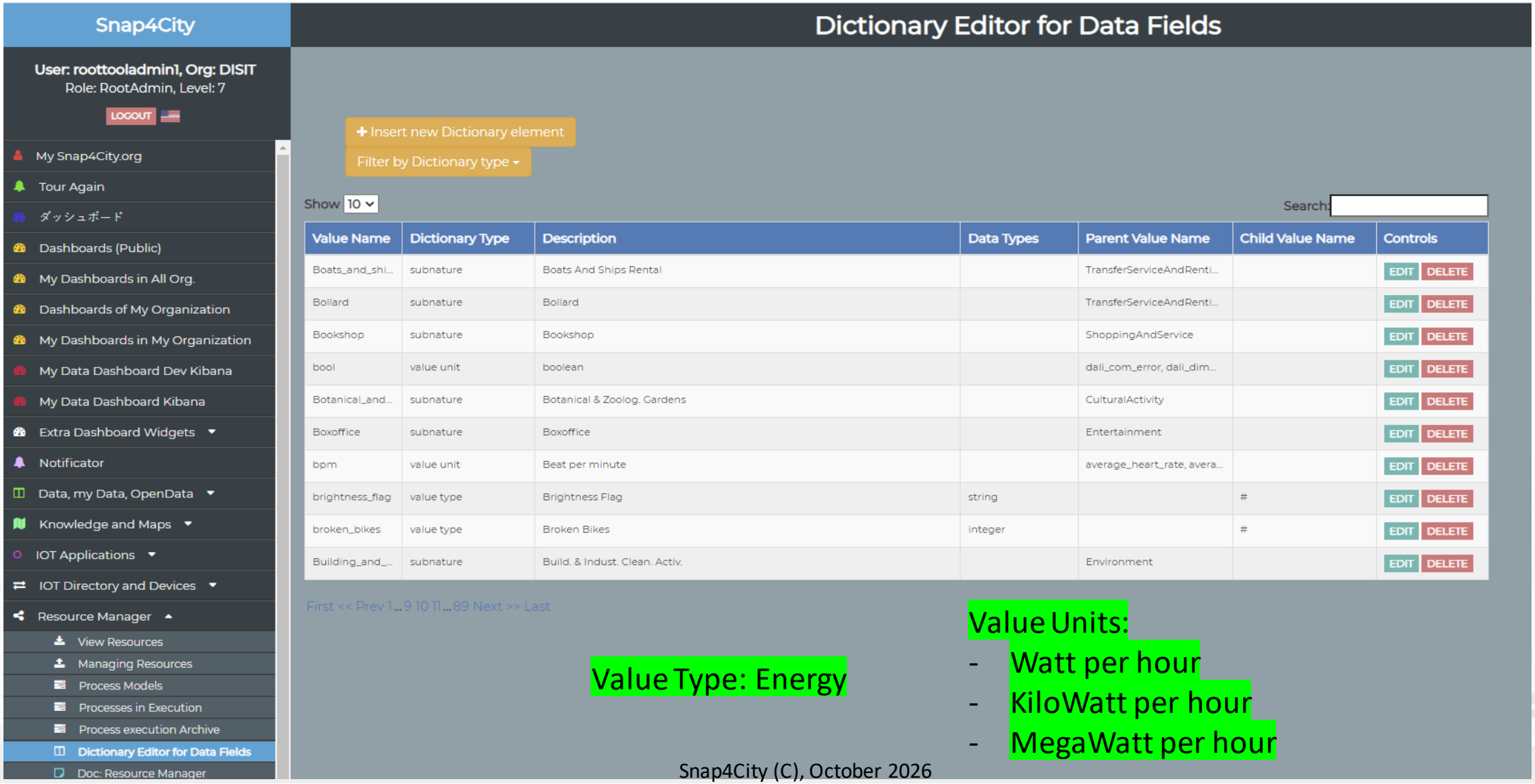
Technical meaning



Link to Friend Sensor as ServiceURI:



Example of Energy and its Value Units



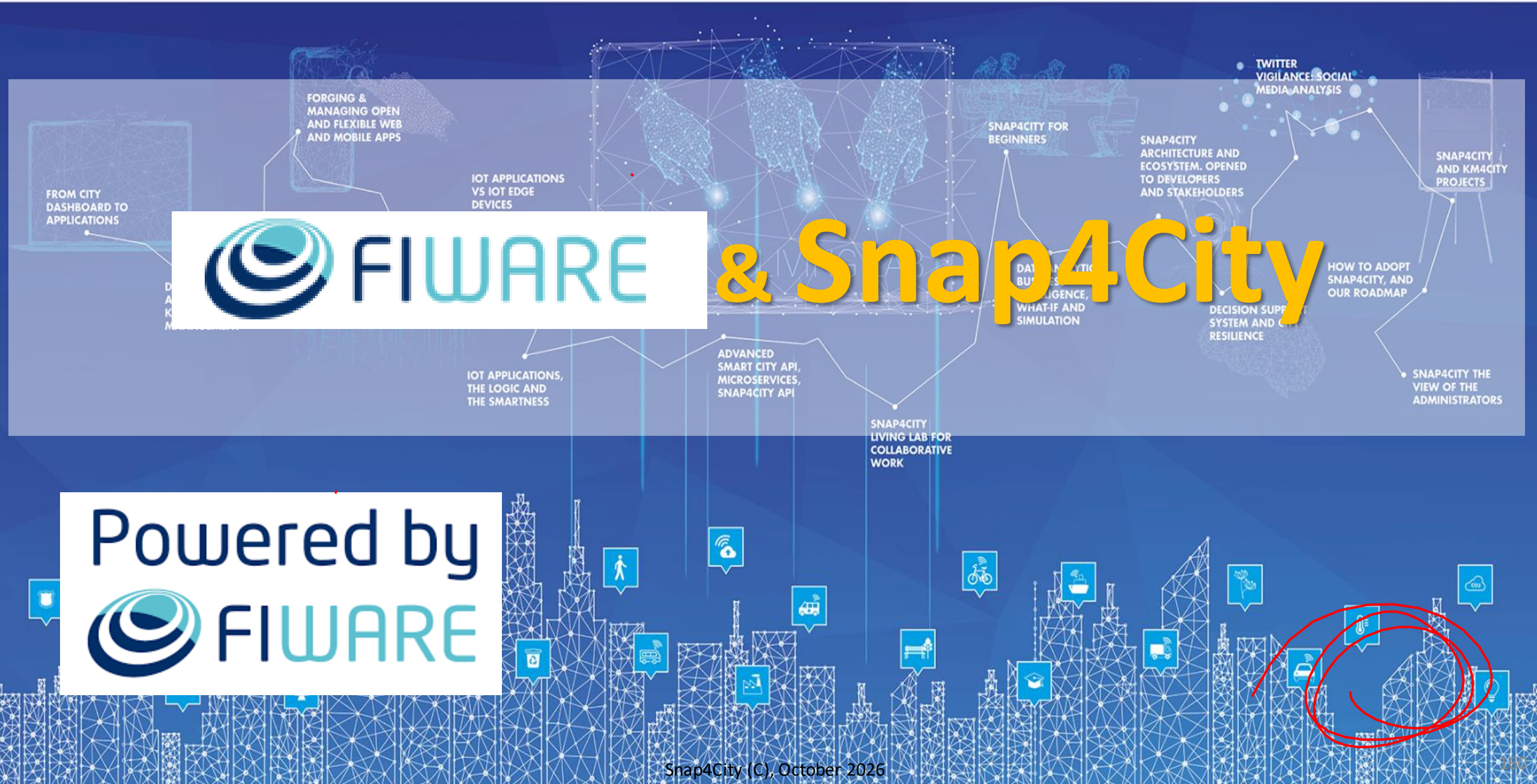
Value Type: Energy

Value Units:
- Watt per hour
- KiloWatt per hour
- MegaWatt per hour

Please note on: Data Type

- Value Types have only a few number of **Data Types** because they represent how the data area treated into the system
- Therefore main Data Types are:
  - **Float**: numbers with decimals large as you like, etc.
  - **Integer**: numbers, booleans (0/1), etc.
  - **String**: url, links, names, id, descriptions, status code, etc.
  - **Json**: structured data, vector, matrices, etc.
  - …..

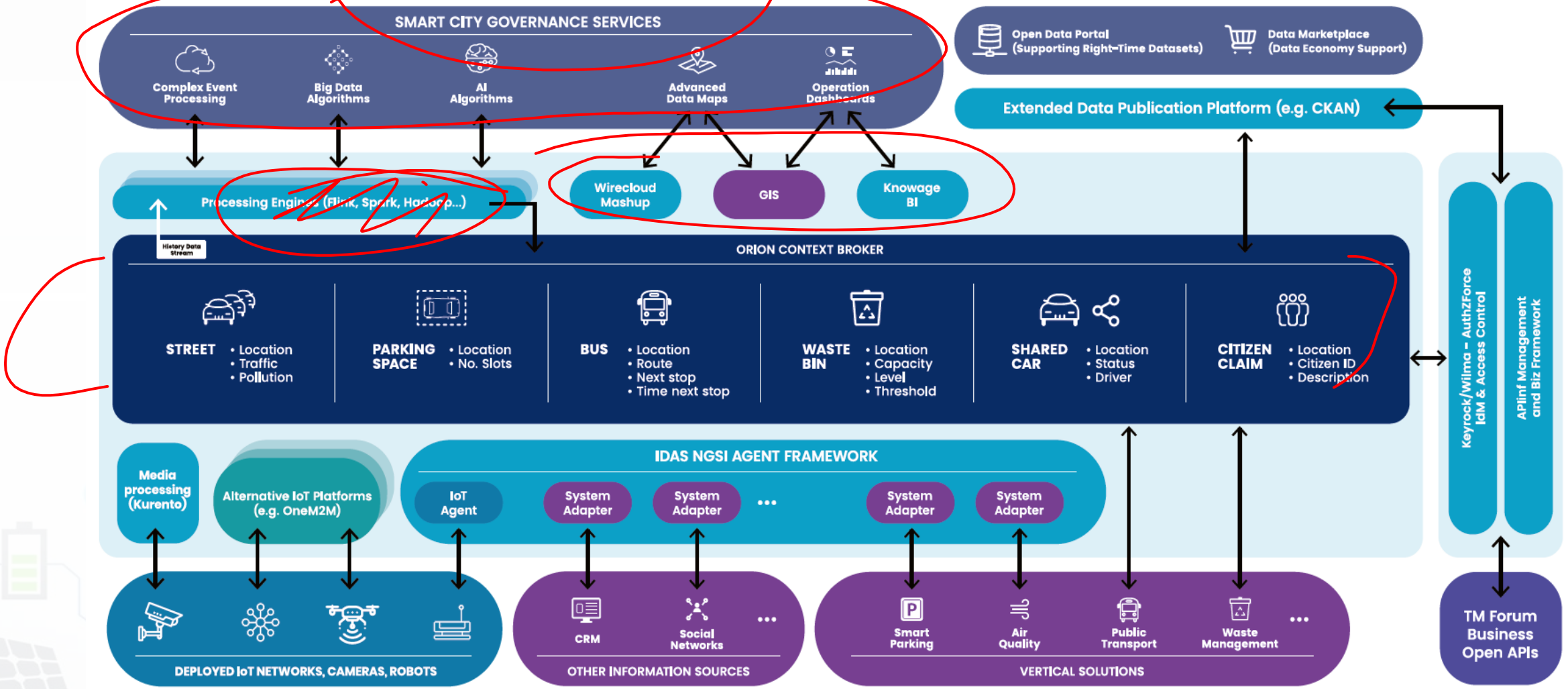
SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES



FIWARE & Snap4City

Powered by FIWARE

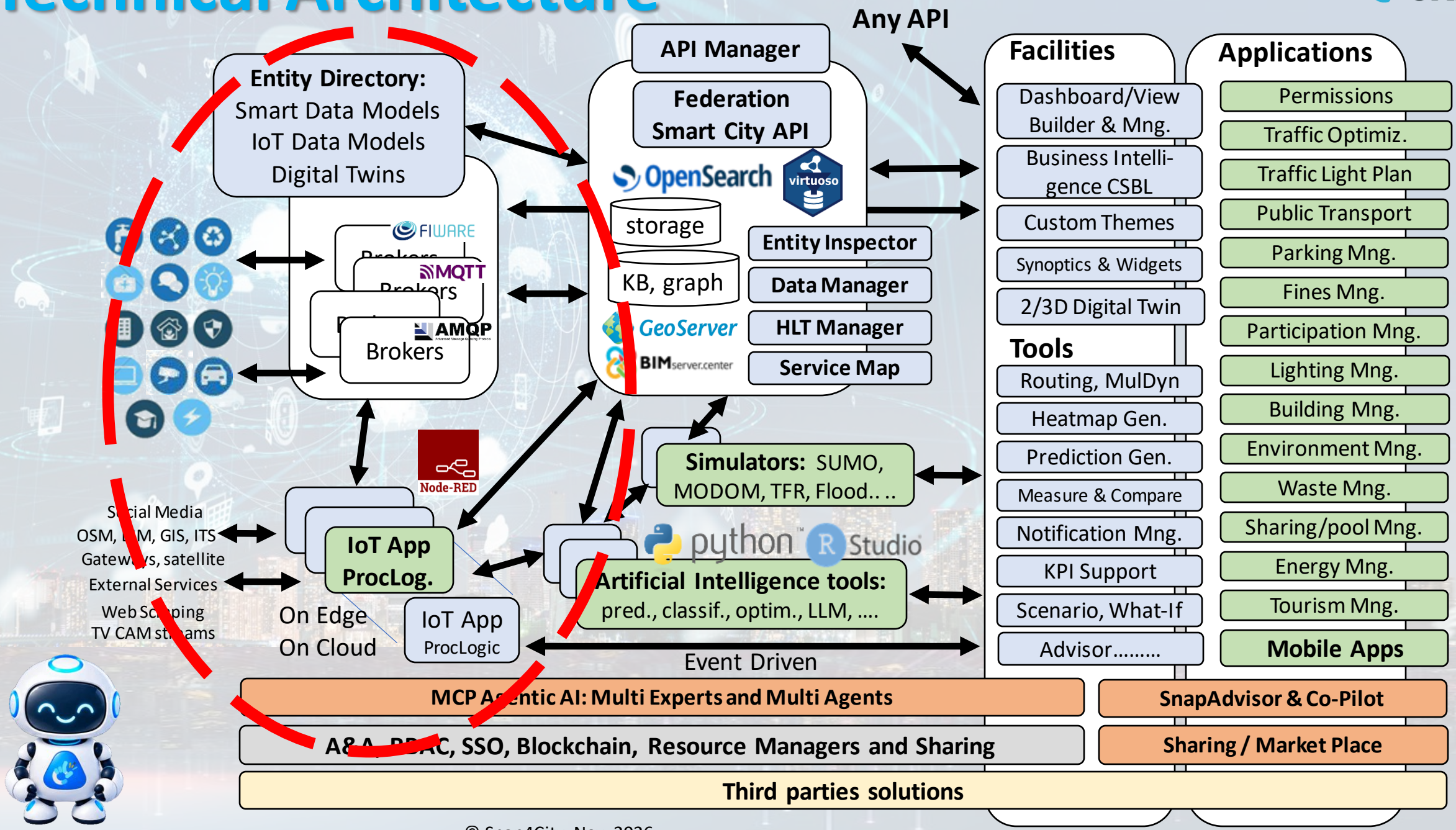
THE FIWARE SMART CITIES REFERENCE ARCHITECTURE



- Snap4City - Powered by FIWARE Solution & Platform:
  - https://www.fiware.org/marketplace/product-details/?category=powered&id=snap4city-snap4city
  - 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

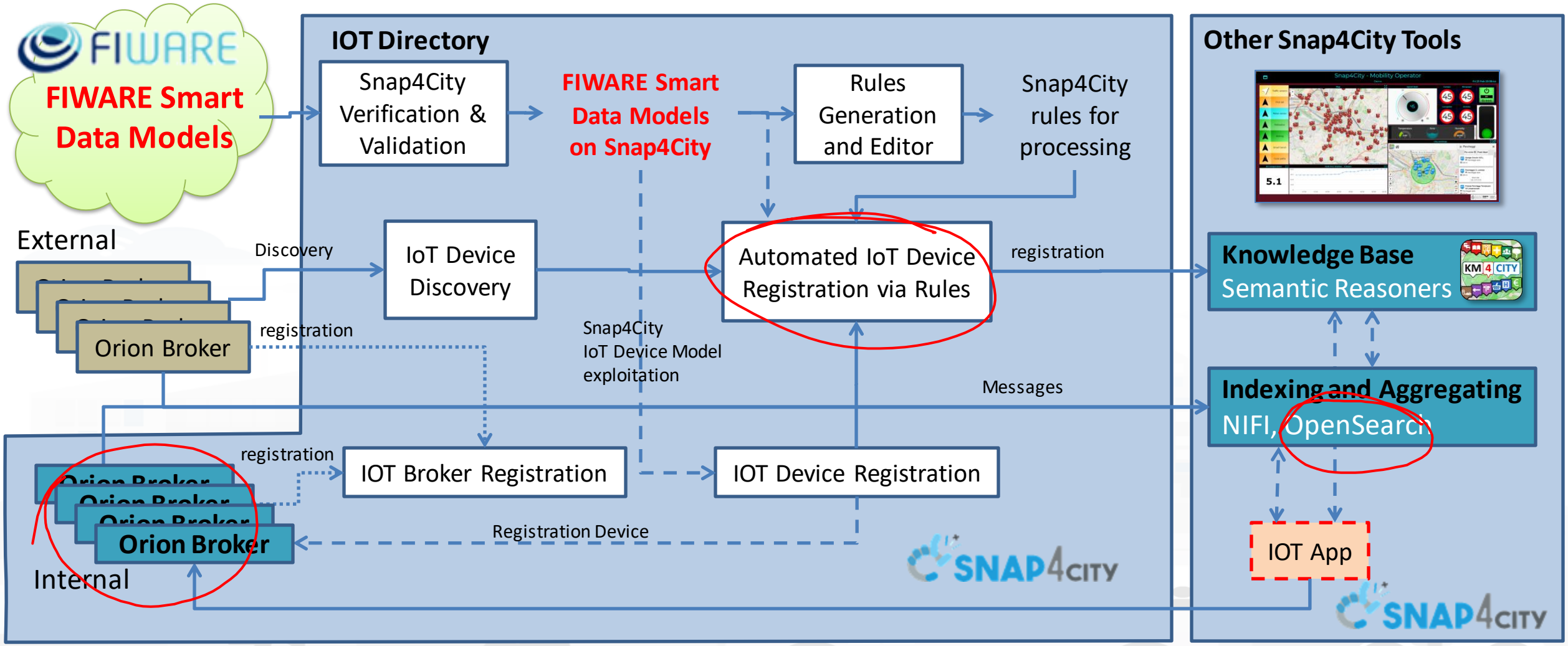
Powered by FIWARE

Technical Architecture

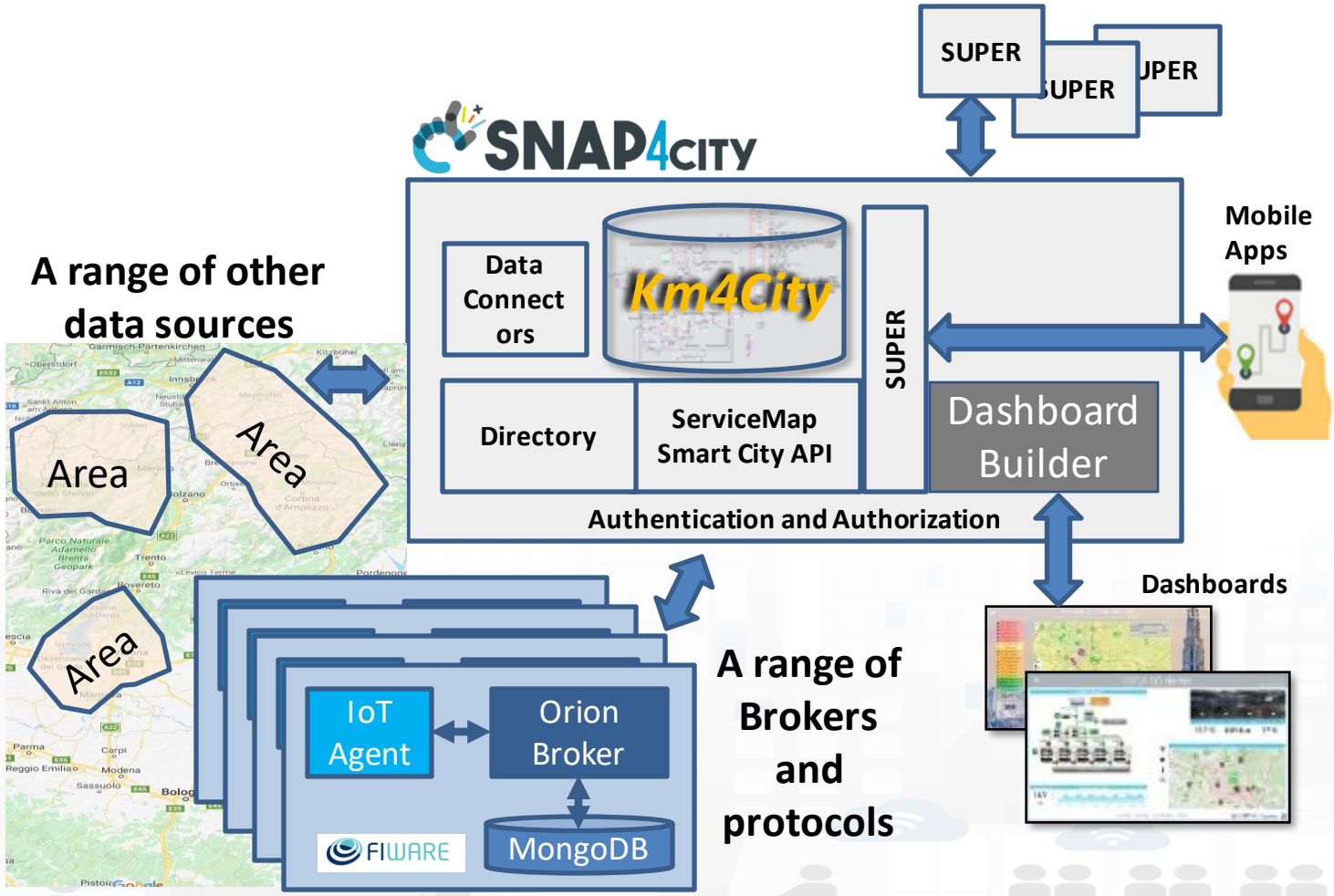


© Snap4City, Nov. 2026

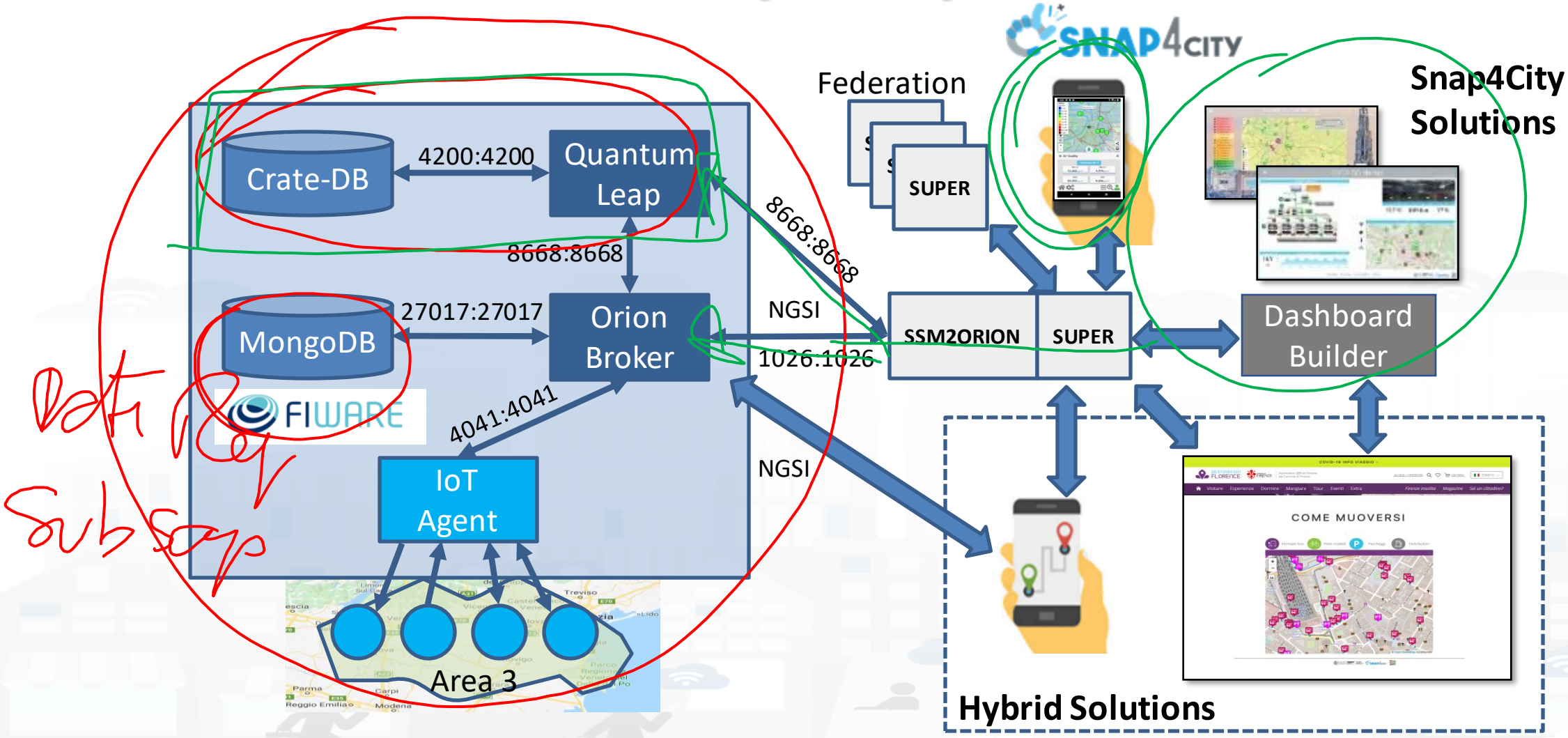
Exploiting FIWARE Smart Data Models



Snap4City IoT Registration and Access



Federation of Snap4City vs ORION Broker



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DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

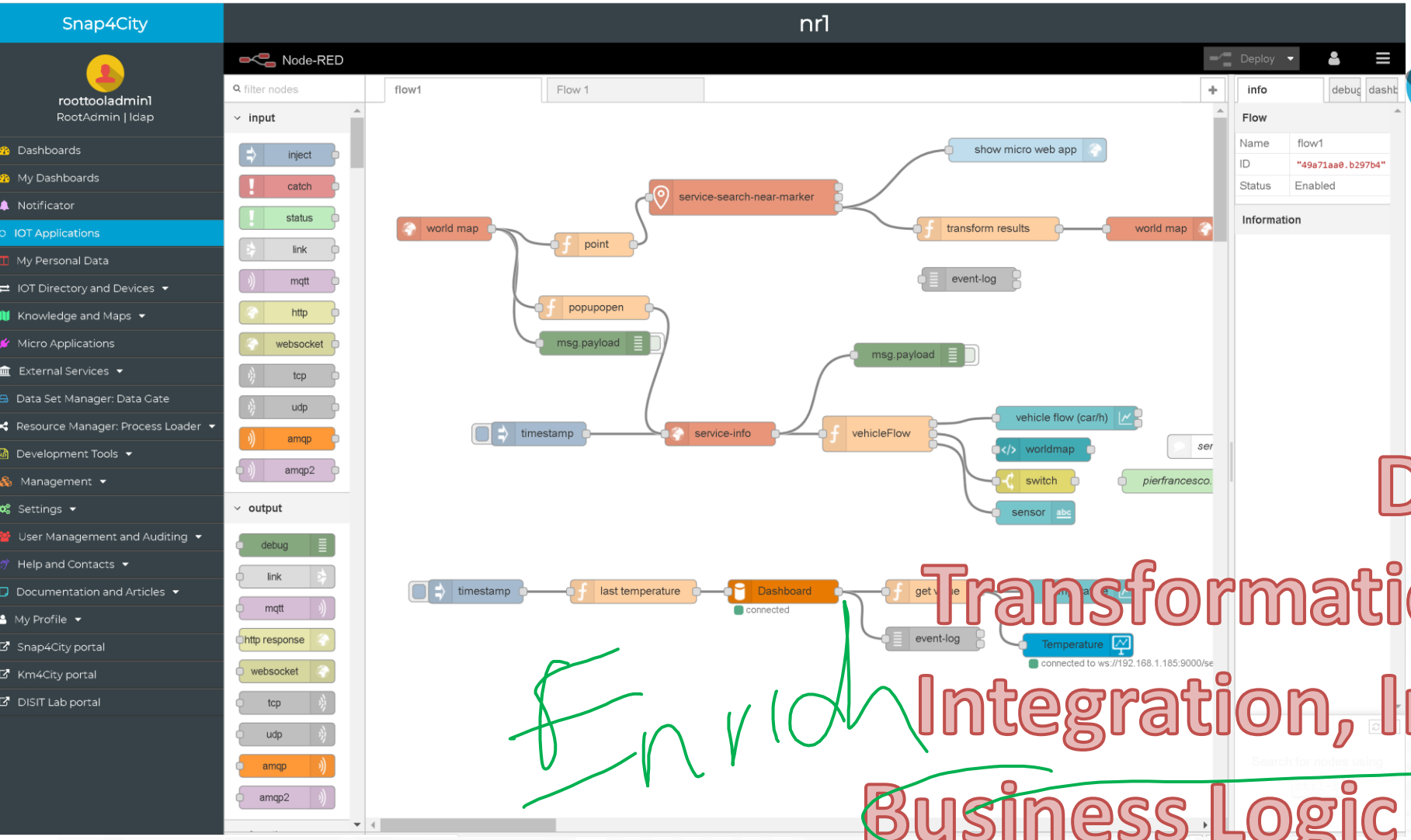
https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

IoT App / Proc.Logic

https://www.snap4City.org

https://www.Km4City.org





Data Adapation
Transformation, Conversion
Integration, Interoperability
Business Logic vs Dashboards
Editing IOT Applications
Data Analytics control
Everywhere: Cloud, on IoT Edge Devices

IOT Application Editor: NODE-RED

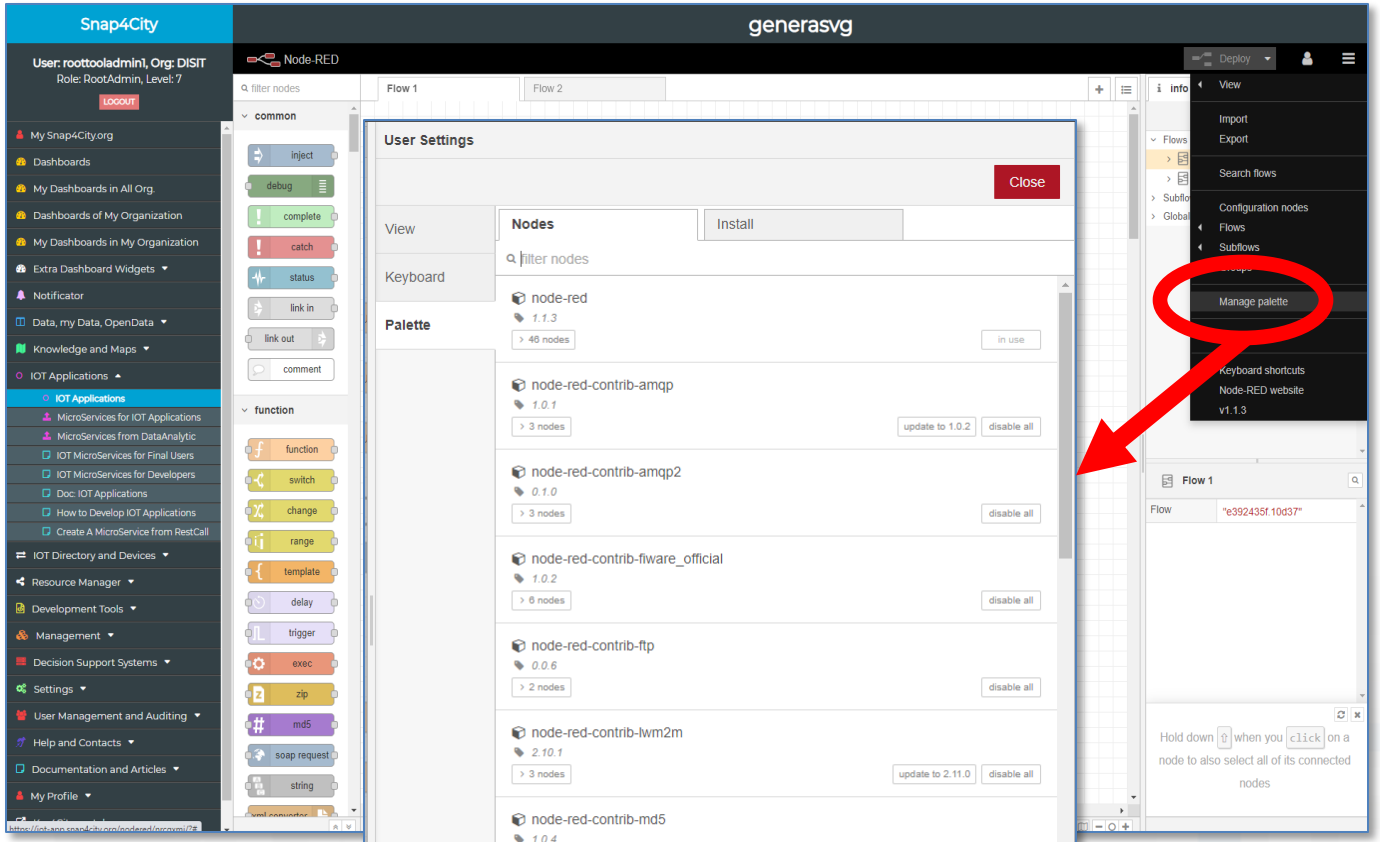
- In the **IOT Application of Snap4City**, it is possible to:
  - Execute flows that process data as: Event Driven, Batch (periodic or not)
  - Create multiple concurrent Flows for each IOT Application
  - Create subflows as macros to be reused
  - Create Groups of nodes as macro
  - **Save/load**, **share**, of nodes, flows and applications with other users via
    - the Snap4City Resource Manager or
    - with JS Foundation or
    - via email, skype, file sharing in general
  - ..

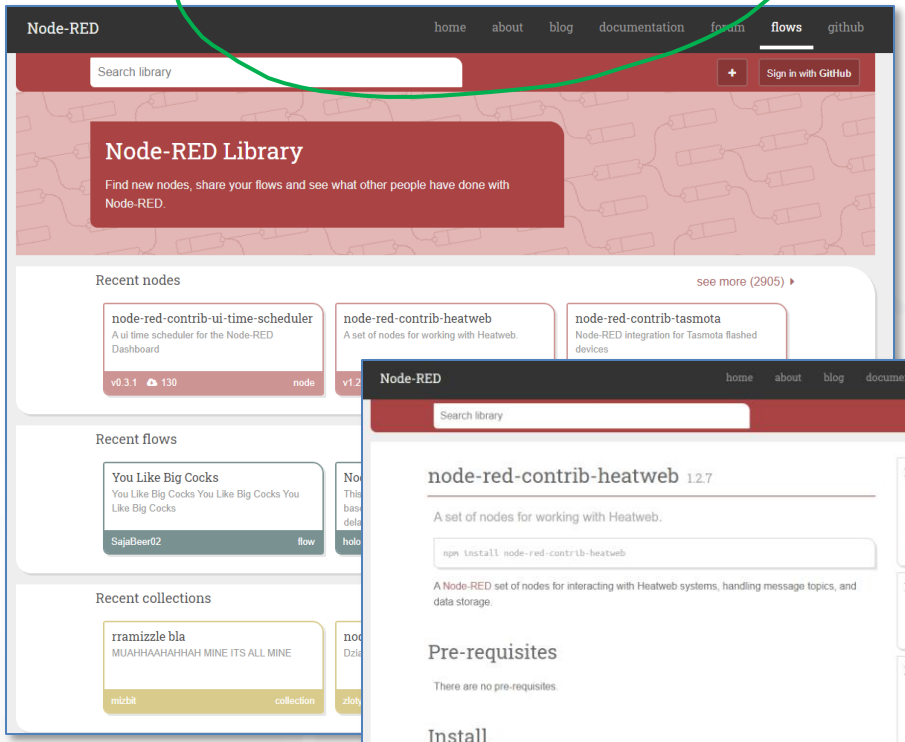
IOT Application Editor: NODE-RED

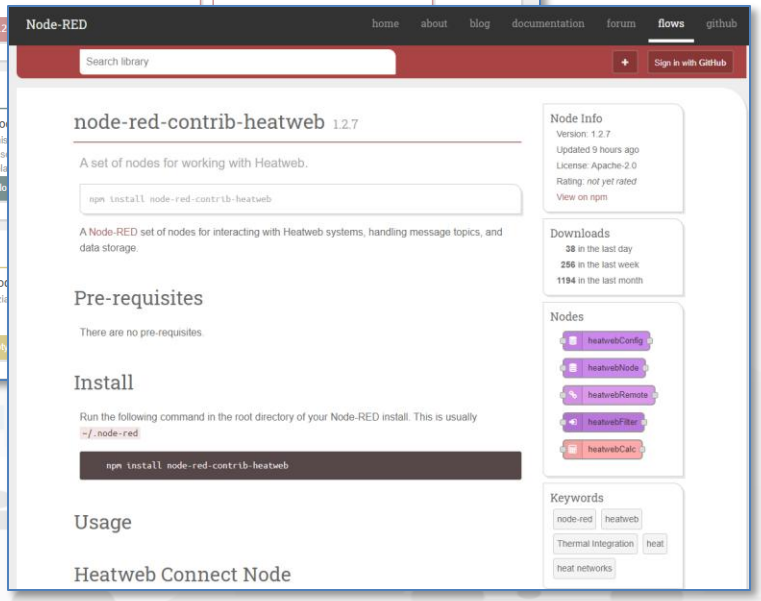
- In the **IOT Apps of Snap4City**, it is possible to Extend the Capabilities:
  - Load other Nodes, segments of flow and entire flows from several sources: email, libraries, S4C repository, etc.
  - Load other libraries of MicroServices/Nodes/Blocks from **Manage Palette**
    - A large set of Libraries of Node is available.
    - The loading may have some limitations for security reasons
  - **Get more IOT Apps** above the Limit that may depend on the organization and/or on personal authorizations, ask to Admin
  - ..

Load Library from Palette

https://flows.nodered.org/

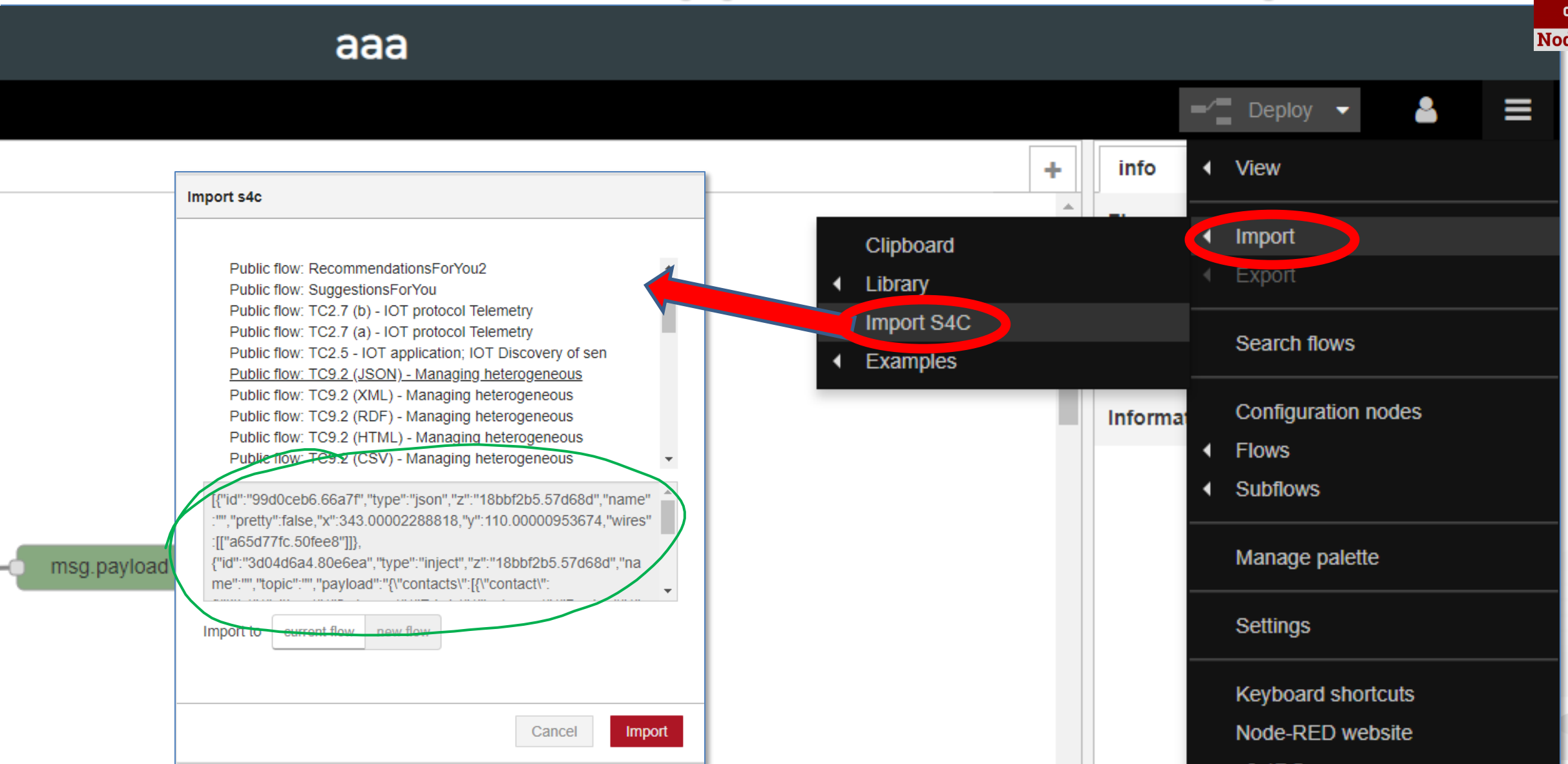




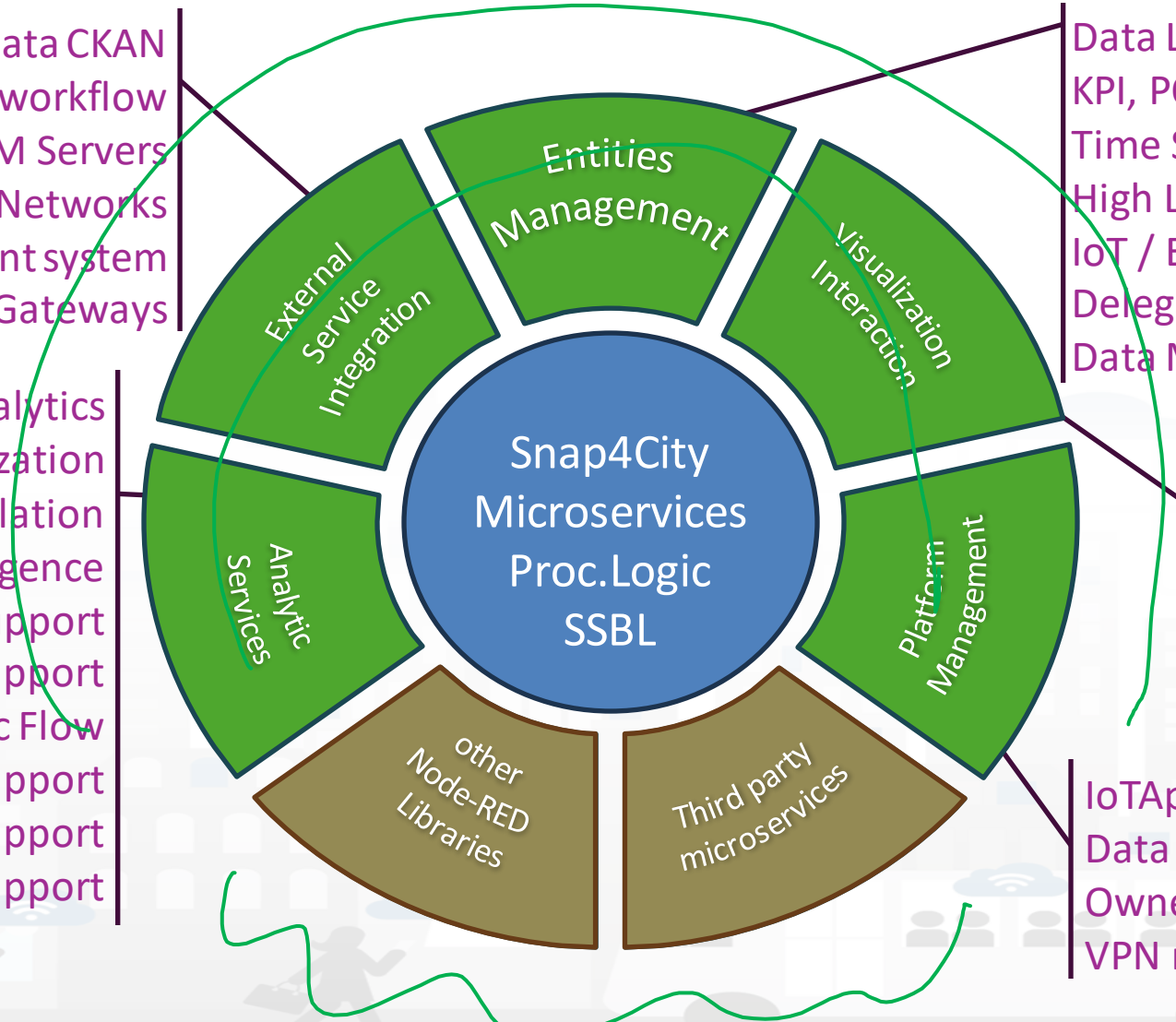


Two views of the same libraries

Load an IOT application of example



MicroServices Areas



Open Data CKAN
Ticket Management, workflow
BIM Servers
Social Networks
Video Management system
Gateways

Data Load / Search / Retrieval
KPI, POI, GIS Data, Scenarios
Time Series, Public transport
High Level Types: heatmaps, ODM,…
IoT / Entity Discovery
Delegation Management
Data Mapping

Data Analytics
Statistic, Optimization
Simulation
Artificial Intelligence
What-if Analysis Support
Geo Utilities Support
Routing & Traffic Flow
MLOps support
Python support
R Studio Support

Dashboards
Widgets: Graphic Libraries
Interactive Widgets
Maps, 3D representations
Synoptics, External Content
Micro Web App

IoTApp Management
Data Logs, A&A, Security
Ownership Management
VPN remote access

Smart City and IOT main needs

Smart City Entities Search: search and access to city entities and their relationships in the city.

Historical Data: search and access to data collected over time into the smart city data aggregator.

Save and Get Personal Data: for many smart city applications, the possibility of saving and retrieval of personal data enables a large variety of smart scenarios for the final users and operators.

Advanced Dashboards: This means to have the possibility of developing a real user interface of the IOT App (to render and produce data for the IOT network).

Data Analytic: The real need in the context of smart City is to have the possibility for a data-analysts of creating some data analytic processes and use it into the flow as MicroService without the intervention of a programmer nor administrator.

IOT Device Connection: This means that the developers expect to have the possibility of using nodes for connecting to a large set of IOT devices using different protocols, and thus connecting to different kind of IOT brokers.

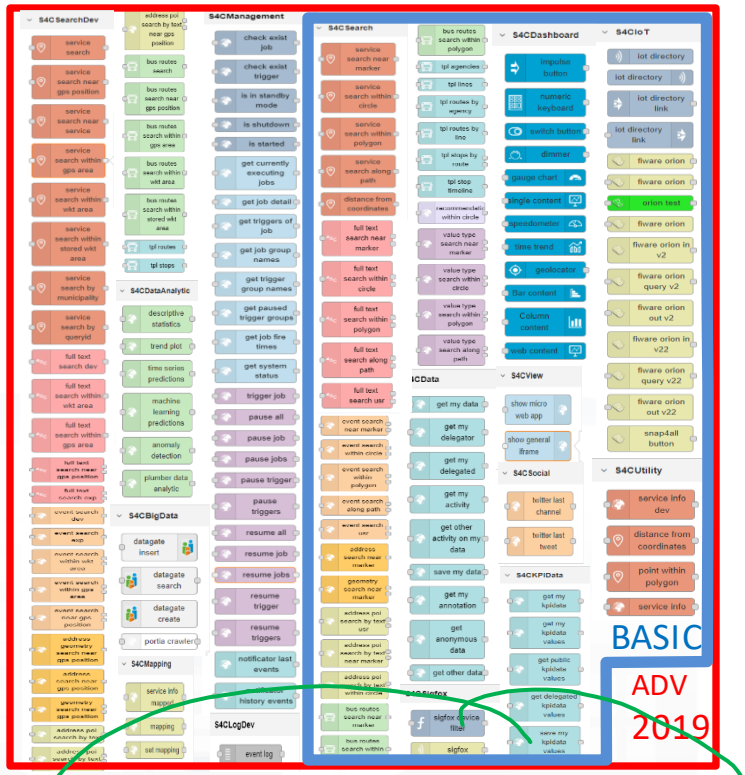
IOT Directory: It should be a single point service for searching, managing and discovering all the IOT Devices which can be connected to the infrastructure by means of a large set of heterogenous IOT Brokers.

IOT Applications

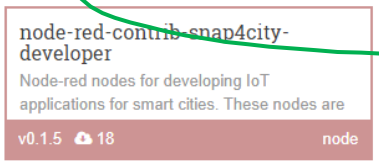
IOT Applications = Node-RED + Snap4City Platform

- A collection of more than **150 MicroServices** have been developed covering the above-mentioned requirements and much more.
- The issue was not only to formalize the MicroServices, but also to create the infrastructure that enable their usage. In many cases, the simple MicroServices hide very **complex** and **sophisticate tools and algorithms (Snap4city Platform)**.
- They are formally distributed as two official libraries of Node-RED nodes (**Snap4City Basic and Advanced**) by the JS Foundation portal.
- They can be **directly installed** in any Node-RED tool of any operating system.





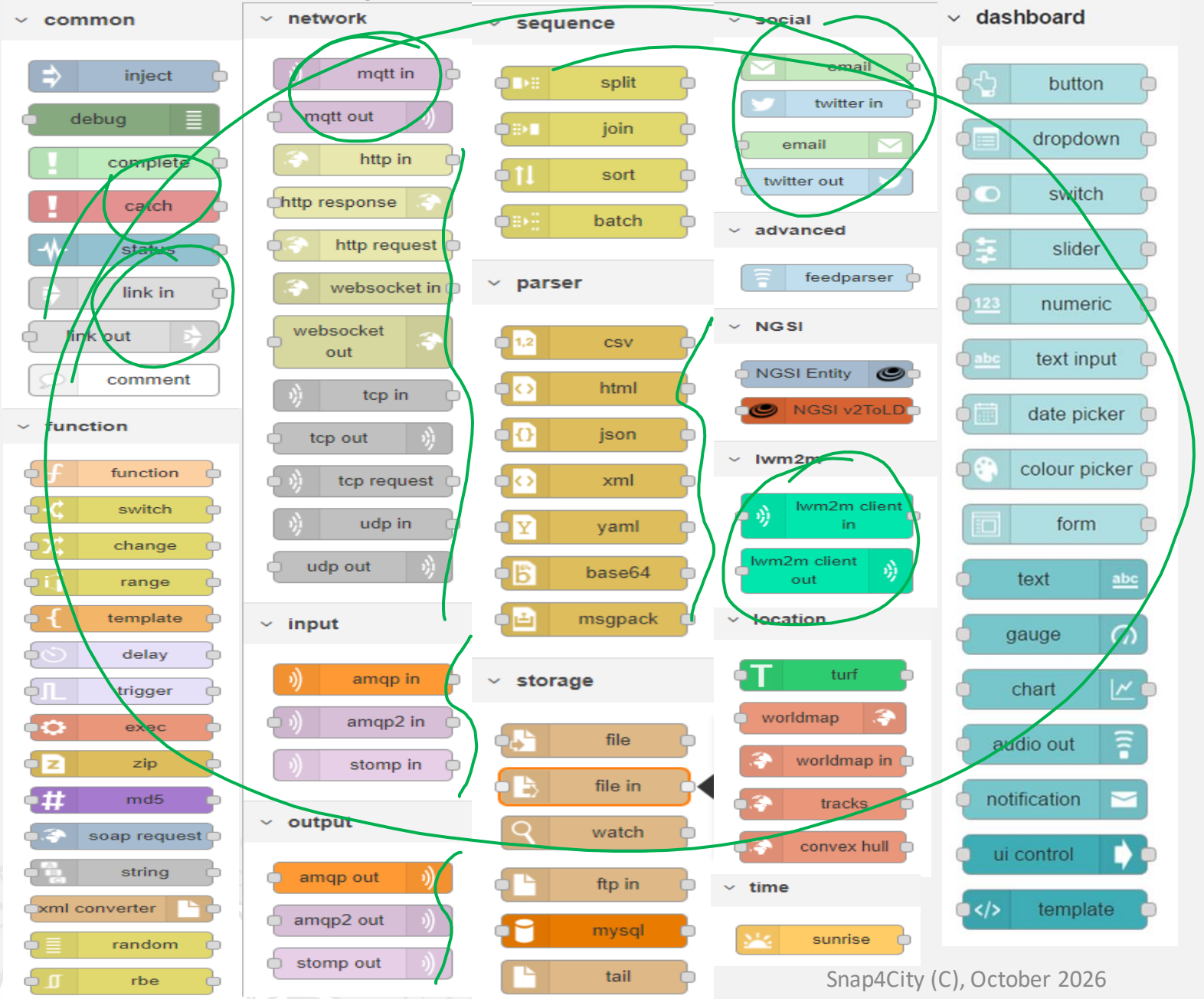
https://flows.nodered.org/?term=snap4city



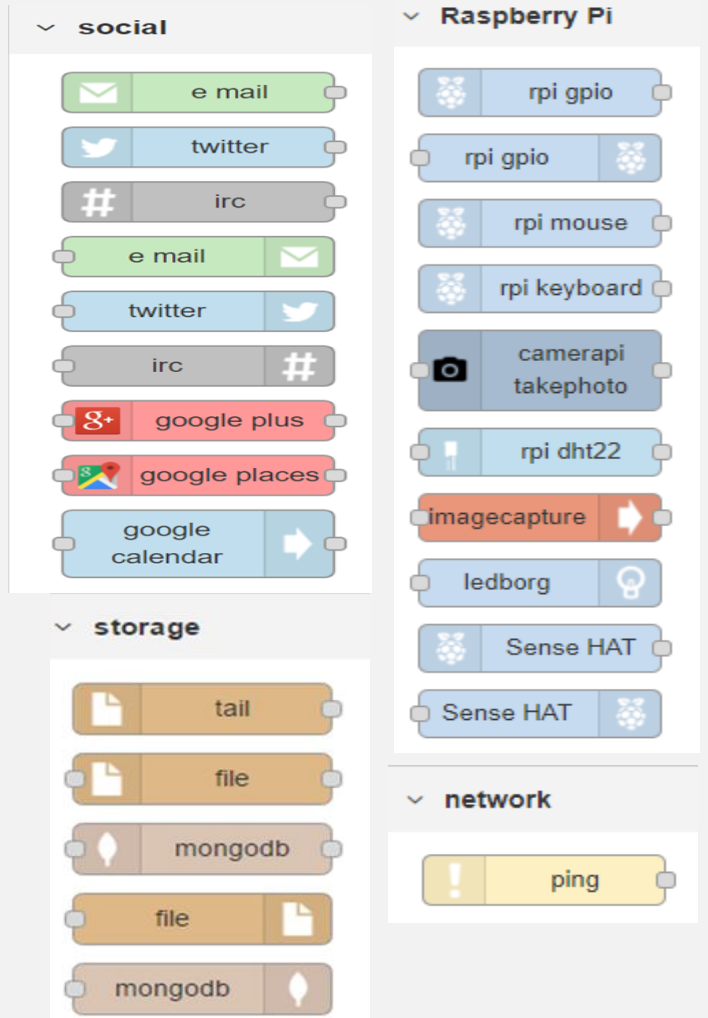


Basic Node.js Blocks on NodeRed on our Advanced IOT Apps

DISIT Lab, Distributed Data Intelligence and ...
... Systems and Interne...
... Information Engi...
http://www.d...



+ on IOT Edge Raspberry

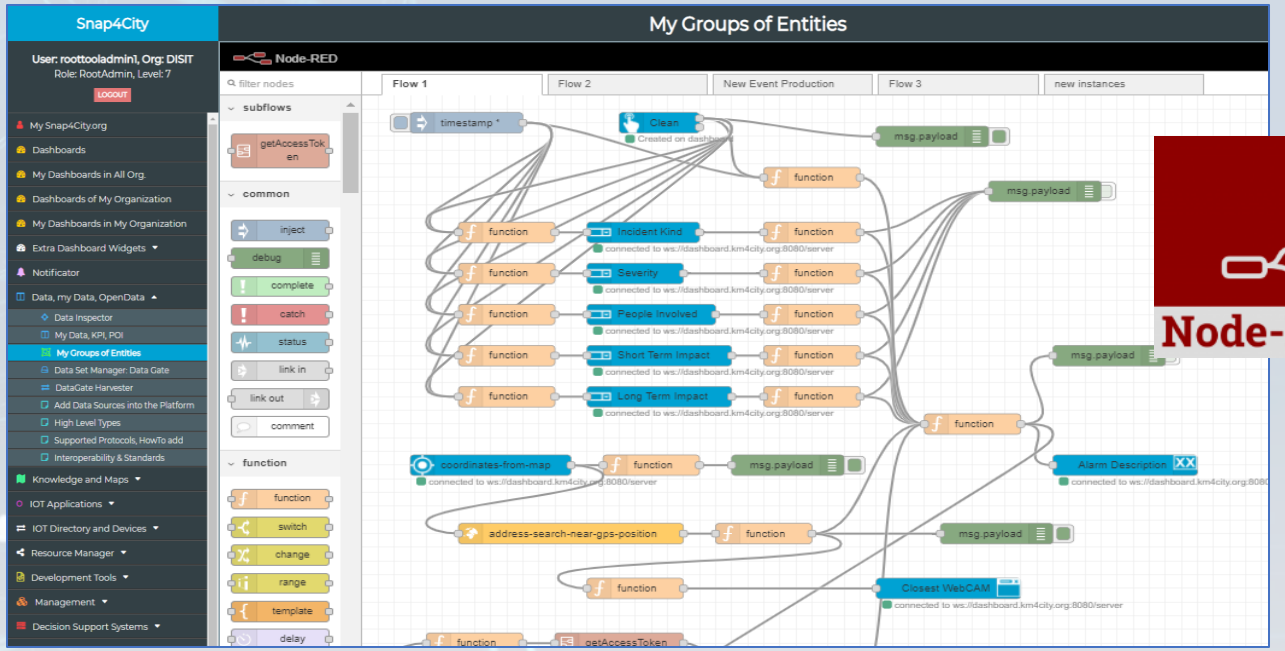


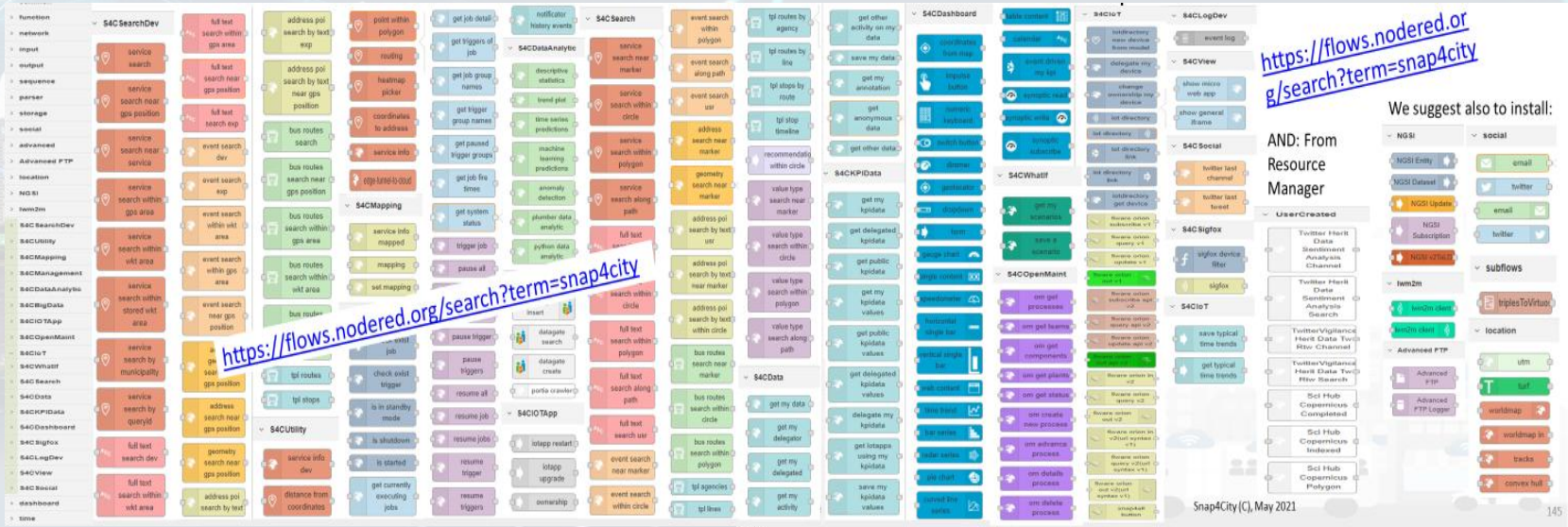
IoT Applications

- **Data ingestion**: more than 70 protocols IOT and Industry 4.0, web Scraping, external services, any protocol database, etc.
- **Data access**: save/retrieve data, query search on expert system, georeverse solution, search on expert system Km4City ontology, etc.
- **Data Transformation/transcoding:** binary, hexadecimal, XML, JSON, String, any format
- **Integration**: CKAN, Web Scraping, FTP, Copernicus satellite, Twitter Vigilance, Workflow OpenMaint, Digital Twin BIMServer, any external service REST Call, etc.
- **Manipulation of complex data**: heatmaps, scenarios, typical time trend, multi series, calendar, maps, etc.
- **Access to Smart City Entities and exploitation of Smart City Services**: transport, parking, POI, KPI, personal data, scenarios, etc.
- **Data Analytic**: managing Python native, calling and scheduling Python/Rstudio containers as snap4city microservices (predictions, anomaly detection, statistics, etc.)
- **User interaction on Dashboard**: get data and message from the user interface, providing messages to the user (form, buttons, switches, animations, selector, maps, etc.)
- **Custom Widgets**: SVG, synoptics, animations, dynamic pins on maps, etc
- **Event management**: Telegram, Twitter, Facebook, SMS, WhatsApp, CAP, etc.
- **Hardware Specific Devices**: Raspberry Pi, Android, Philips, video wall management, etc.

Ingestion, aggreg. → exploitation

- **IoT App Visual Programming, no coding**
  - Data transformation
  - Integration, Interoperab.
  - Scripting Data Analytics
  - Data ingestion
  - Business logic
- **Edge and Cloud**
- **MicroServices** data driven develop via visual language Node-RED



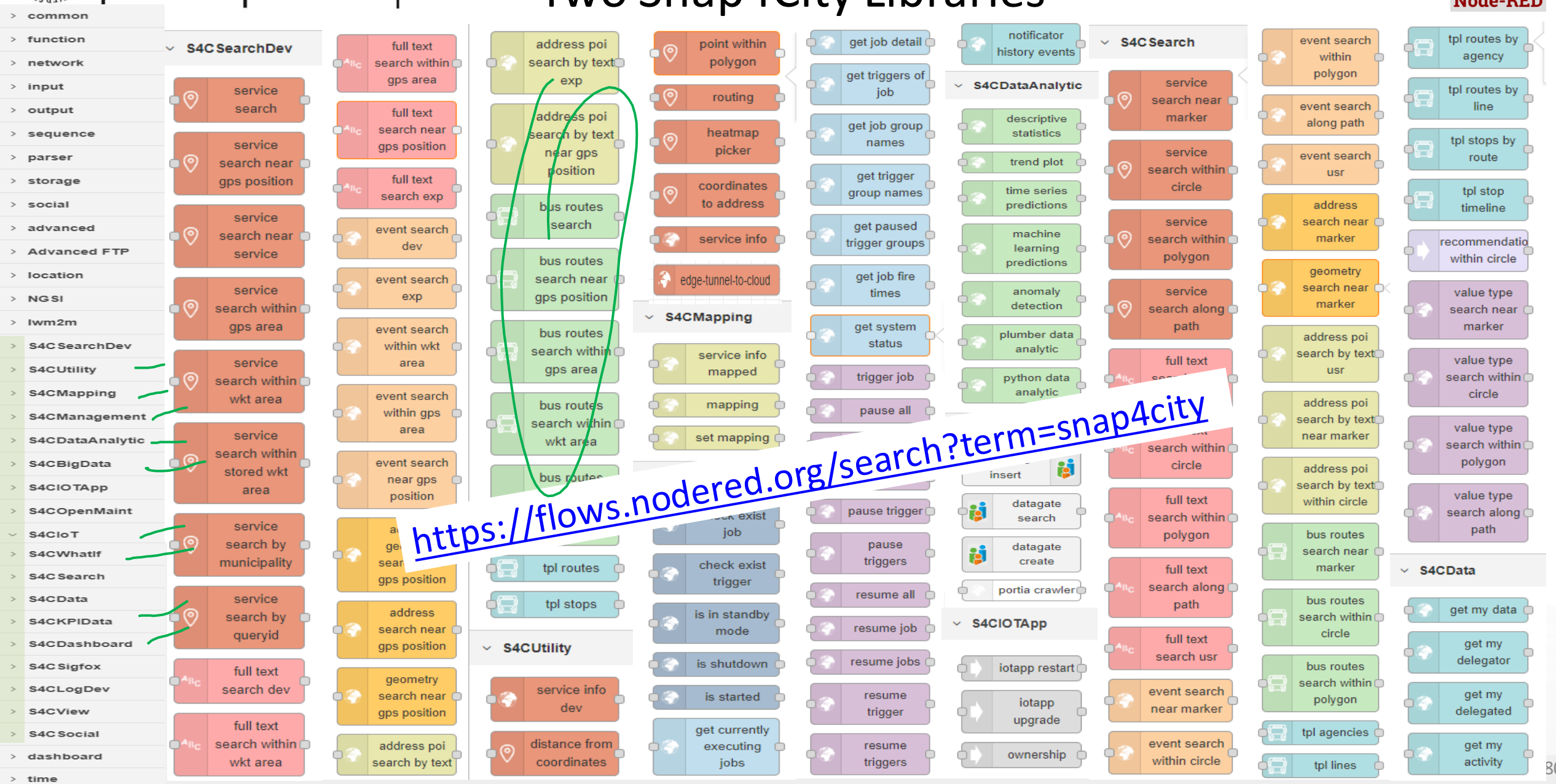


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2024 collection
Two Snap4City Libraries

SNAP4CITY | Node-RED

https://flows.nodered.org/search?term=snap4city



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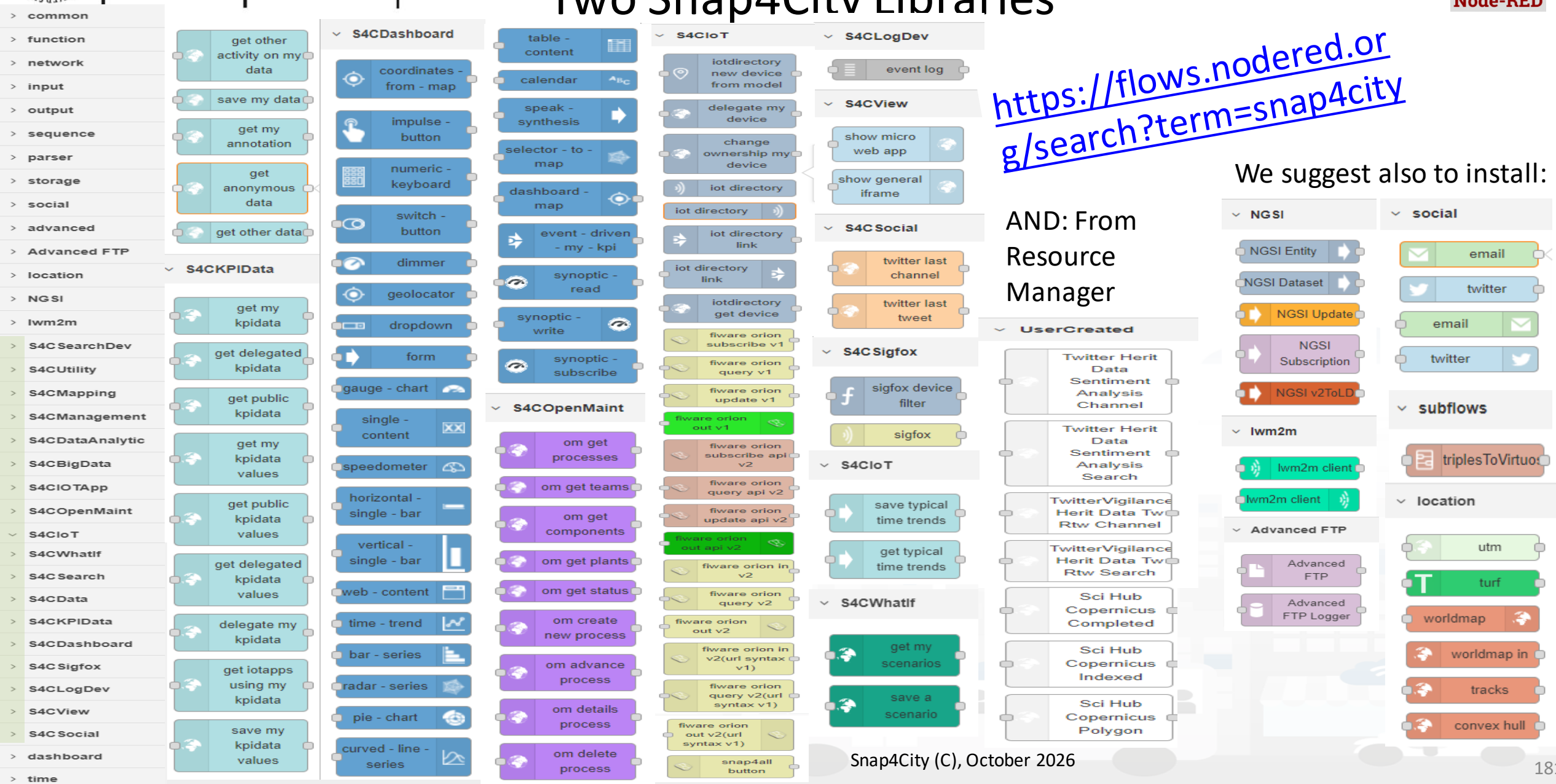
2024 collection
Two Snap4Citv Libraries

SNAP4CITY | Node-RED

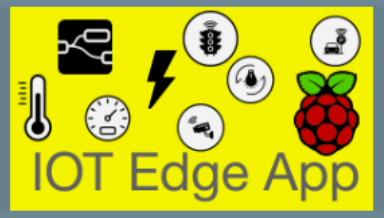
https://flows.nodered.org/search?term=snap4city

We suggest also to install:

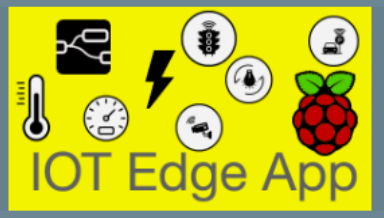
AND: From Resource Manager



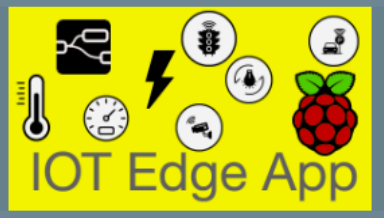
IOT Applications

2018-09-14T04:44


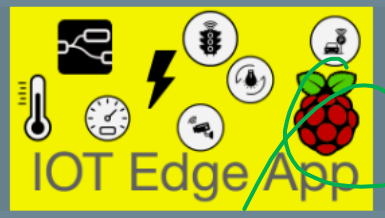
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Management

2018-09-21T03:19


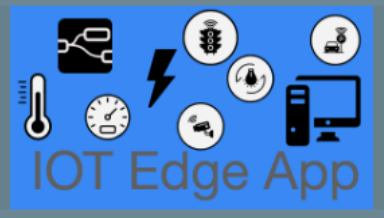
owner: panesi
Management

2018-10-19T16:07


owner: pb3
Management

2018-10-19T17:17


owner: pb3
Management

2018-10-22T11:57


owner: semolarudy
Management

application


owner: tester5
Management

F/b APP

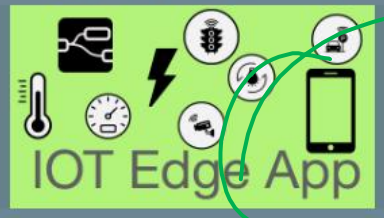

owner: semolarudy
Management

ChargingStations


owner: comunedashres
Management

Deprecated - SiiMobilityControlRoom


owner: badii
Management

SamsungGalaxyS4BarCode


owner: badii
Management

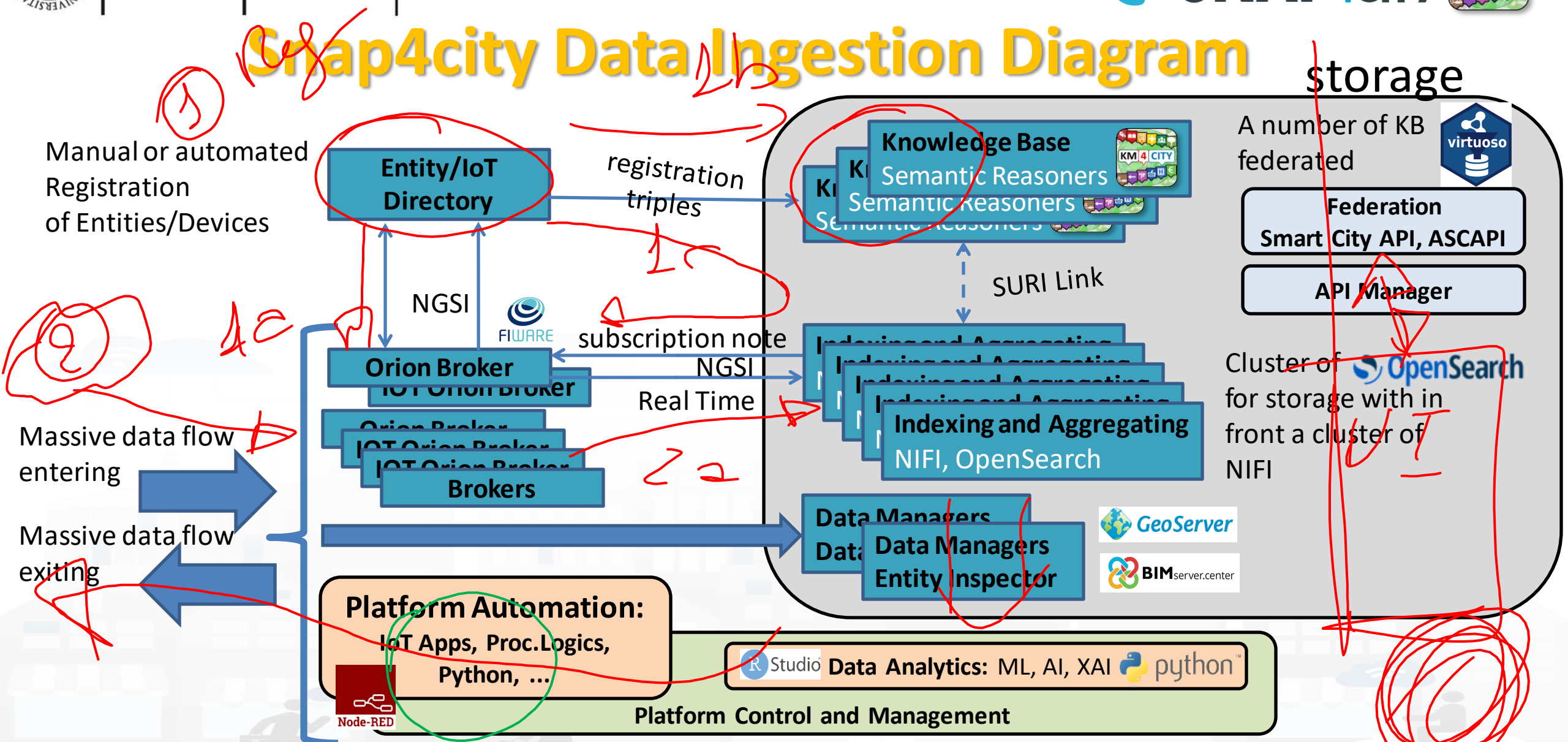
esercitazione


owner: tester2
Management

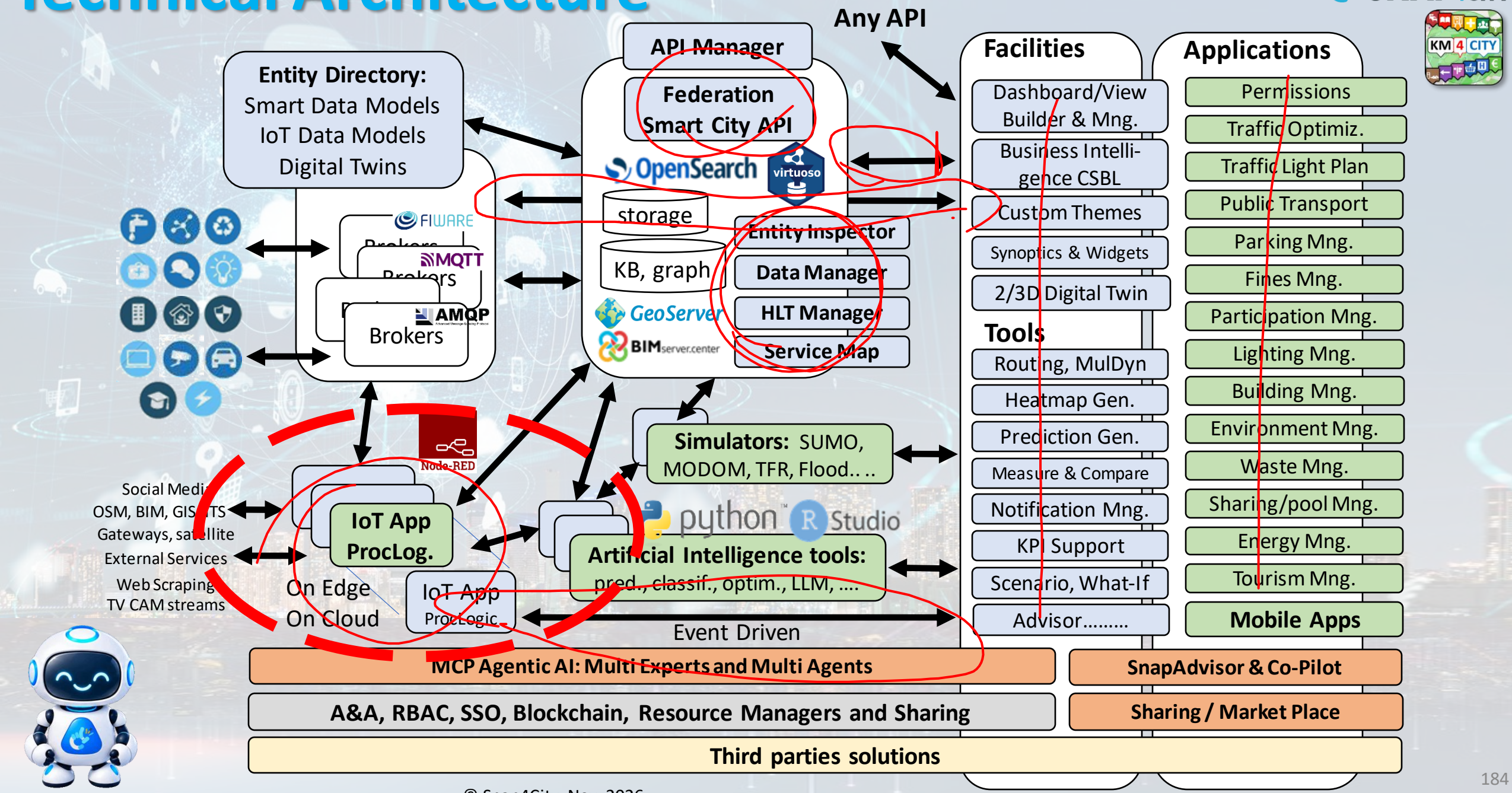
Iot-App


owner: tester14
Management

Snap4city Data Ingestion Diagram



Technical Architecture

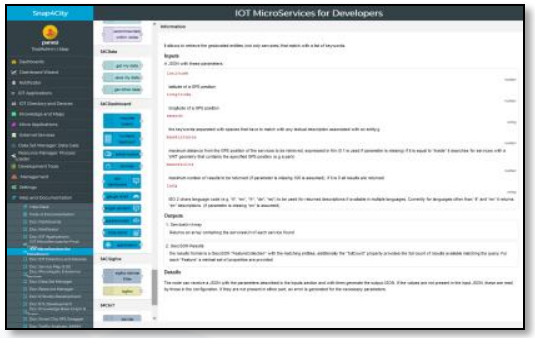


© Snap4City Nov 2026

Proc.Logic / IoT App Development

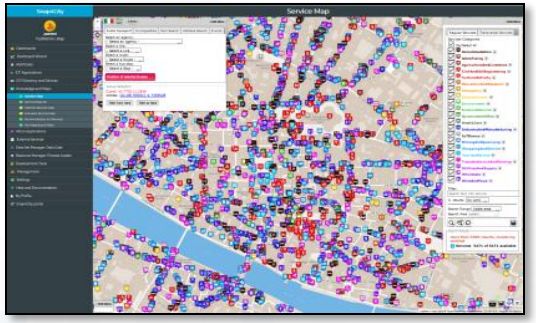
IOT Discovering

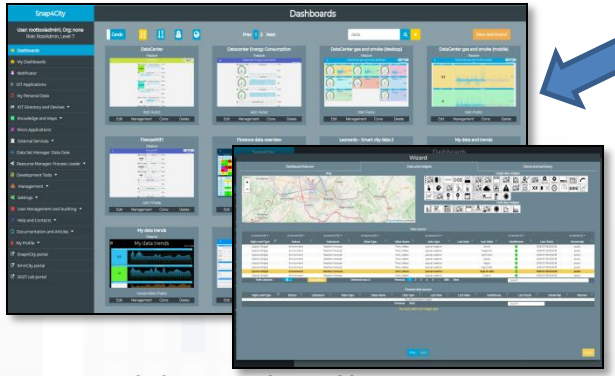
MicroServices collections



My IoT Applications







ServiceMap Discovery

Knowledge Base, Km4City



Dashboard Collection, Editor and Wizard

IoT App. Editor



Generating IoT App With Dashboard



Sharing/saving reusing IoT App



Resource Manager

GitHub



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DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

Comparisons

https://www.snap4City.org **https://www.Km4City.org**



Market Solutions

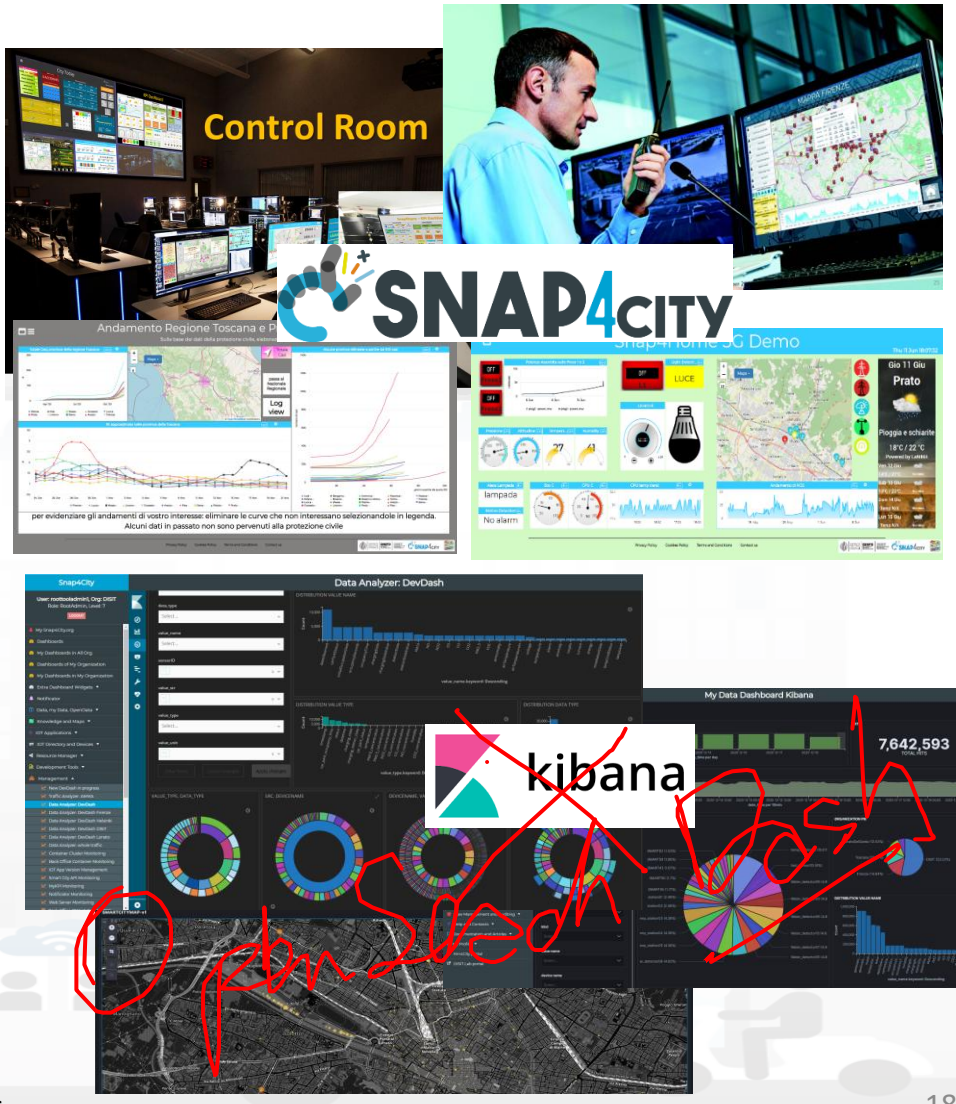
	Open Source end-to-end	Scalability IOT	Execution scalability	Visual Programming end-to-end applications	Advanced Smart City API, MicroServices Multi Domain Semantic Platform	External sevices via API	Standard based Modules and IOT, Open Devices Integrated	Community manmagement Resoruce Sharing	Referral data management	Security end-2-end	Dashboard H24/7	Falxible and easy dashboard creation	Multi-protocol on IOT
SNAP4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
KAA	Y	Y	Y	N	Y	N	Y	N/Y	Y	N	--	Y	Y	N	Y
AWS	N	Y	Y	N	N	N	Y	Y	N	Y	Y	Y	Y	(Y)	Limited
Azure IOT	N	Y	Y	(Y)	N	N	Y	Y	(Y)	Y	Y	Y	Y	(Y)	Limited
IOT IGNITE	Y	Y	N	Y	N	N	Y	N	N	N	--	N	Y	(Y)	MQTT
PTC ThingWorkx	N	Y	(Y)	Y	N	N	Y	Y	N	N	--	Y	Y	(Y)	Y
BEZIRK	Y	N	N	N	N	Y	--	Y	N	N	--	N	N	N	Y
Bosch IoT Suite	N	Y	(Y)	Y	Y	N	Y	Y	N	N	Y	Y	Y	(Y)	Y
FIWARE ref SC arc.	Y	(Y)	N	N	Y	N	N	Y	N	N	N	N	Y	N	Y
CISCO Jasper	N	Y	N	N	N	N	Y	N	--	--	Y	--	Y	--	N
IBM Watson IoT	(N)	Y	(Y)	Y	Y	Y	Y	Y	N	Y	(y)	Y	Y	Y	Y
Siemens MindSphere	N	Y	--	Y	N	N	N	Y	N	N	Y	N	Y	N	Y
Carriots	N	Y	--	N	N	N	Y	--	N	N	--	N	Y	Y	MQTT
Thingsboard	Y	Y	N	N	N	N	N	N	N	N	--	Y	Y	Y	(MQTT, CoAP, http)
IOT eclipse.org	Y	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	Y
Google IOT	N	Y	Y	N	N	N	Y	N	N	N	N	Y	N	N	MQTT, HTTTP

Requirements on Broker Interoperability

Requirement	Snap4City	Google IoT Cloud	Azure IoT	AWS Amazon	IBM Watson	Siemens Mindsphere
Manage different kinds of IoT entities	Y	N	Y	(Y)	Y	Y
Connect External and Internal Brokers	Y	Y	Y	Y	Y	(Y)
Use any Data Model with any data type	Y	Y	(Y)	(Y)	Y	(Y)
Verify the correctness of IoT Messages of IoT Devices	Y	(Y)	(Y)	(Y)	(Y)	(Y)
Semantic Interoperability	Y	Y	Y	Y	Y	(Y)
Automatics deploy of Internal IoT Brokers	Y	N	N	N	N	Y
Register External Brokers	Y	N	N	N	N	N
Discover IoT Devices on IoT Brokers	Y	N	(Y)	N	(Y)	N
Easy management graphic interface to list and test IoT entities	Y	(Y)	(Y)	(Y)	(Y)	(Y)
Manage IoT Device Model and Device Data Type ownership and access grant	Y	Y	(Y)	Y	Y	Y

Two Main Lines for Dashboarding are present

- **Dashboard Builder of Snap4City**
  - For accessing and browsing data on: OpenDistro x ElasticSearch, Mongo, MySQL, Smart City API, Super and thus from federated Smart City API, etc.
  - Supports sensors/actuators: data driven data, maps in extended manner, data driven widgets, large collection of widgets, direct IoT Connections, custom widgets, animated PIN on maps, a large set of panel/widgets, etc.
  - Very simple to be used for control room, decision makers, situation rooms, operators, etc.
  - Very well integrated with IoT App, Custom widgets, animation, external services.
  - Very simple to be customized for non programmers since all the tools are visual.
  - Support for GDPR and deep control of access.
  - Can integrate Kibana/Grafana Views into a Widget
- **Kibana** (so called **DevDash**, **AMMA** and recently **My Dashboard (Dev) Kibana**), also accessible as Grafana
  - For accessing and browsing data on OpenDistro x ElasticSearch storage and other sources supported
  - No Support for real time event driven widgets/panels, actuators and synoptics, no sophisticated maps, etc.
  - Not simple for control room, decision makers, etc.
  - Not integrated with IoT App, Custom widgets, animation, external services.
  - Oriented to developers, complex production of custom views, etc.
  - Partial support of GDPR and deep control of access.



Snap4City Dashboard Builder (2023) vs Kibana/Grafana

Features	Snap4City Dashboard Builder	Kibana, Grafana
Large Collection of Widgets, also from D3 library	YES	Nothing
Custom Widgets SVG of any kind, full defined process for customization	YES	Nothing
Real time event driven widgets and data	YES	Nothing
Server/Client Side Business Logic for data transformation with visual programming: Node-RED	YES: visual/coding	coding
Maps with custom PIN, bubbles, animated and moving, etc.	YES	Nothing
Maps with paths, shapes, traffic flow, scenarios, routing, heatmaps, what-if, Origin Destination Matrix, …	YES	Nothing
Maps with Orthomaps from WFS, WMS, GIS connection, etc.	YES	Nothing
TV camera integration and selection	YES	Nothing
Widgets for business logic integration on real time: buttons, selector, switch, etc.	YES	Nothing
Kiviat, Spider net, Calendar (also any other D3 Widgets)	YES	Nothing
Typical Time Trends: day hours, month week, month days, …..	YES	Nothing
Time Trend Compare: day, week, month, year	YES	Nothing
Selectors/Menus: text, icons, etc., also in connection with IOT APP, Node-RED	YES	Nothing
Full control of graphic layout, font, colours, refresh per widget, etc.	YES	Nothing
Iframe integration of third party widgets and web pages, nesting dashboards, embedding Kibana	YES	Nothing
Connection among multiple Dashboards and Widgets	YES	Nothing
Synchronization with Video Wall, and Operators Views	YES	Nothing
Multiseries, bar lines, charts, pie, donut, simple selectors, trends, etc., also from business logic	YES	Limited
Single content, string, html, any data, etc.	YES	Limited
Special widgets: Weather forecast, civil protection, road plates, Twitter, SVG, etc…	YES	Nothing
Digital Twin Local (BIM) and Global (3D city representation) with 3D traffic, Heatmaps, Devices, …	YES	Nothing
Faceted search	YES: selectors, forms, buttons	YES

Functional: FIWARE ref arc wrt Snap4City solutions

	FIWARE ref arc smart city	Snap4City
Multiple Protocols: IoT, Databases, etc..	10 on IOT, Limited on databases, etc.	More than 200, very very wide
Large set of high level types: maps, trends, heatmaps, traffic, trajectories, scenarios,…	No	Yes:
Integration with workflows, BPM	Not Supported	Yes: bidirectional
Integration and Modeling Digital Twin BIM	Not Supported	Yes: bidirectional
Integration with GIS: WFS, WMS	Not fully supported	Yes: bidirectional
Integration with Heatmaps and Satellite	Partially, not calibrated	Yes: fully; calibrate and multiple versions, animations
Integration with Satellite	not supported	Yes: fully
Smart City API	no	Yes
Open Data Management	Partial with CKAN	Yes, Fully automated with CKAN
Federation of platforms	Partial on brokers	Full on Brokers and Knowledge base and API
Semantic model and queries	with NGSI-LD in the future	Yes since 2013
Multiple kinds of IoT Brokers	No, only agents	Yes: NGSI, COAP, AMQP, MQTT, SigFOX, etc.
Data Model	Smart Data Models	Smart Data Models, IoT Device Models
Complex data Model	Not supported	Heatmap, traffic flow, ODM, 3D models, TV Cam, etc.

Interoperability
Openess

Functional: FIWARE refarc. wrt Snap4City solutions

	FIWARE ref arc smart city	Snap4City
Data Transformation	Coding	Yes: IOT App, Node.JS, Visual Programming, scalable
Data Analytics	No	Yes
on line development	No, limited	Yes: Rstudio, Python, Tensor Flow, MapReduce, etc.
Dashboard on data	Grafana no LDAP	Yes: Dashboard Builder, OS Dash with GDPR, LDA
Dashboard Widgets	Limited, no custom, coding needed	Yes: A wide range including custom widgets, secure compliant, animations, configuration, also open to new development
Real Time end-to-end from Dashboards to any other channel, event driven	No, very limited	Yes, fully supported
Multi Data Map	Limited with non OS	Very extensive, with multiple widgets and sync
MicroApplications	No	Yes
Auditing, Assessment, accounting	No, no, no	Yes, Yes, Yes
Multitenacy on data management	No only on broker	Yes: on Broker, on data management, on dashboards, etc..
Living Lab for creating/managing communities/groups	Not supported	Yes: provided in the open source
Report generation/management	No	Yes

Process
Graphics
Manag.

Market Solutions

	OT Discovery Abstraction	Authentication, Authorization	Security end-2-end, secure on OT and Dashboards	Open HW and Open SW	Integrated Community management	Data Types: IOT Devices, IOT App, Dashboard, Data	Data Type: Publish/share, Delegation, Consent and change	Data Type: Download and Delete	Auditing on Data Type Access	Open Source end-to-end	Scalability IOT	Visual Programming end-to-end applications	Advanced Smart City API, MicroServices	Multi Domain Semantic Platform	Standard based Modules and OT, Open Devices	Resource Sharing	Data Analytics integrated	Dashboard H24/7, protected connection	Multi-protocol on IOT
		G				G	G	G	G										
Snap4City	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
KAA [53]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	N	(Y)	N	N	Y	Y
Thingsboard [55]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT,coap, http
IOT eclipse.org [56]	N	N	N	(Y)	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N	N	Y
IOT IGNITE [57]	N	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	N	N	N	N	N	Y	MQTT
FIWARE [47]	N	Y	N	Y	N	N	N	Y	N	Y	(Y)	(N)	Y	N	Y	N	N	Y	Y
ARM mbed IoT [48]	Y	Y	Y	Y	Y	N	(N)	N	Y	Y	Y	N	N	N	Y	N	N	Y	Limited
Airvantage [51]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	MQTT, HTTP
AWS [43]	Y	Y	Y	Y	N	Y	(N)	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
Azure IOT [44]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	Y	(Y)	Y	Limited
PTC ThingWorkx [59]	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	N	Y	N	N	Y	Y
Bosch IoT Suite [58]	Y	Y	Y	Y	Y	(Y)	(N)	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Y
CISCO Jasper [55]	Y	Y	Y	Y	N	(Y)	(N)	N	Y	N	Y	N	N	N	N	--	(Y)	Y	N
Siemens MindSphere [60]	Y	Y	Y	(Y)	N	Y	(N)	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	Y
Carriots [54]	Y	Y	Y	(Y)	N	Y	N	N	Y	N	Y	N	N	N	--	N	N	Y	MQTT
Google IOT [45]	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP
Homekit Apple [50]	Y	Y	Y	Y	N	Y	N	N	Y	N	(Y)	N	N	N	N	Y	N	Y	Limited
Smarthing Samsung [52]	Y	Y	Y	Y	Y	Y	(Y)	Y	Y	N	(Y)	N	N	N	N	N	N	Y	Limited

Plataforma	Lenguajes	Recursos	APIs	Despliegue	Observaciones
PROMENADE	Java	Kubernetes, Apache Kafka, Flink	RESTful, WebSockets	Contenedores	Código no disponible en el momento de la prueba
Mi-FIWARE	Java, Node.js	FIWARE	RESTful, NGSI, SocketIO	Contenedores	**Seleccionada para Evaluación**
VirIoT	Python	Docker, Kubernetes, Kafka	RESTful, NGSI	Contenedores	**Seleccionada para Evaluación**
ITrade	Java, JavaScript	Kafka, Pulsar	RESTful	Contenedores	Pocos proyectos, enfocada en IoT solamente
Snap4City	Python, Java, JavaScript, PHP, Node-RED	Kibana, Km4City, FIWARE	RESTful, WebSockets, NGSI	Contenedores, VMs	**Seleccionada para Evaluación**
Sentilo	Java, JavaScript	–	RESTful	VMs	Enfoque en gestión de sensores
OpenRemote	Java, Python, C++	UI	RESTful	Contenedores	Pocas implementaciones
Sapparchi	Java, Ruby	Nginx, Kafka, otros	RESTful	Contenedores, VMs	Código no disponible en el momento de la prueba

UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

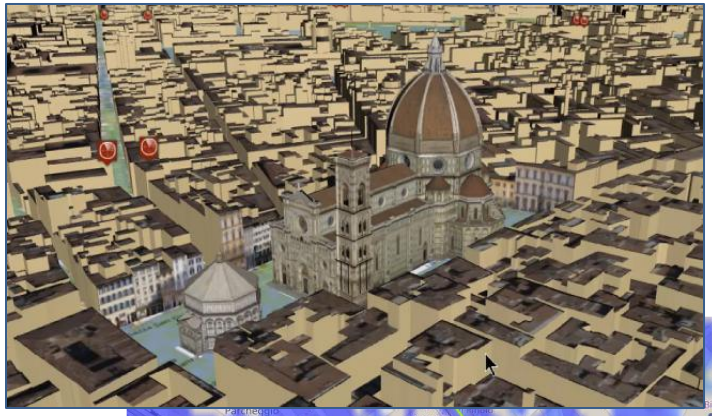
From Operation to planning

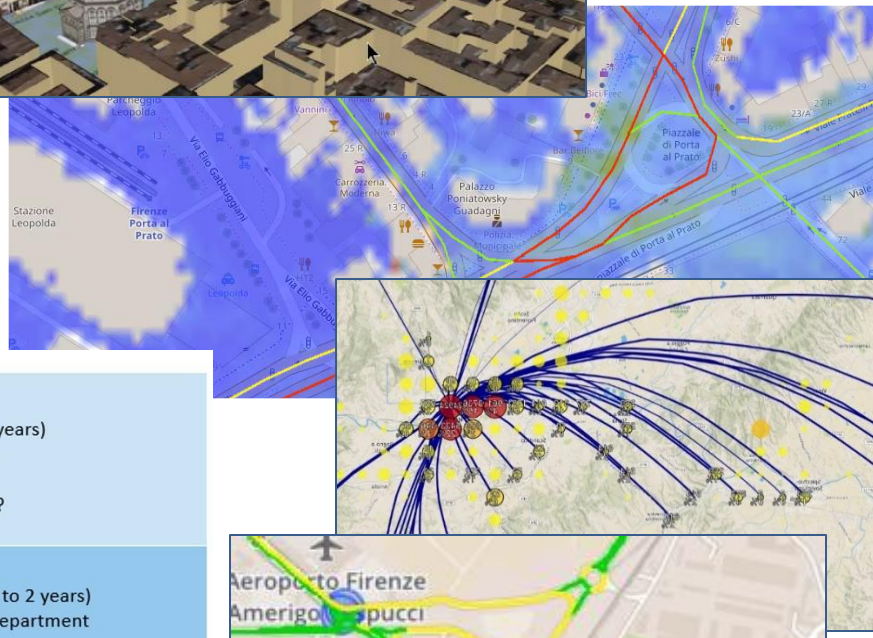
https://www.snap4City.org **https://www.Km4City.org**



Main Tasks

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Computing predictions data from the field and KPI
  - Anomaly detection
  - Early warning on critical conditions
- **Making plan: tactic and strategic, medium and long range**
  - Optimisation: Prescriptions, suggestions
  - Risk assessment
  - What-if analysis on scenarios
    - Simulation and predictions
  - Resilience
- **Be ready for Unexpected Unknows**



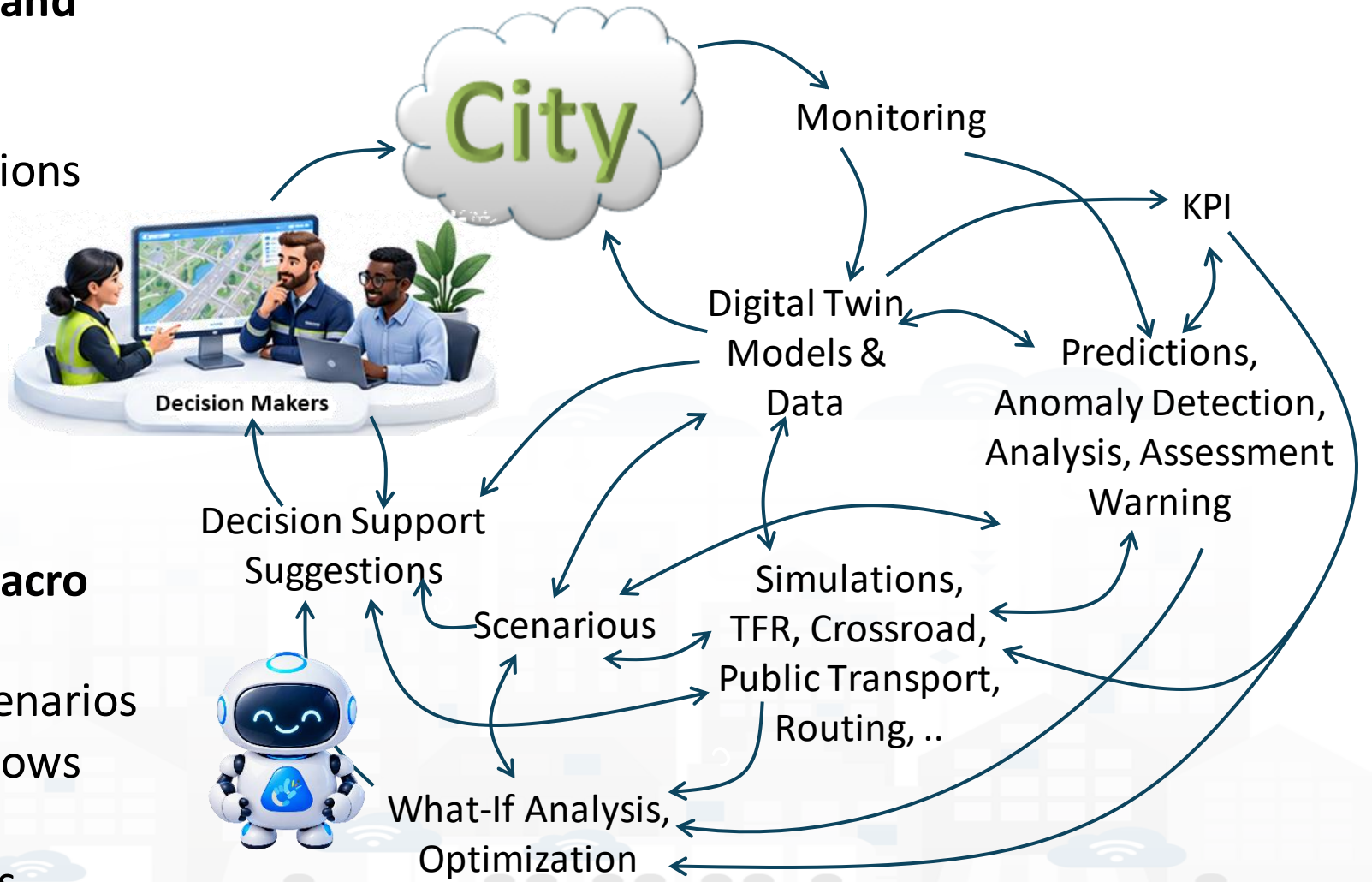






Agentic Tasks

- **Controlling Status: management, and operational**
  - Monitoring via KPI
  - Early warning on critical conditions
  - Predictions vs KPI
  - Anomaly detection
  - Neuro-Symbolic analysis
  - Risk assessment
  - Fast What-if analysis
- **Making plan: tactic and strategic, medium and long range, micro/macro**
  - Simulation & optimization
  - Generative AI Prescriptions, scenarios
  - Resilience to Unexpected unknows
  - What-if analysis wrt scenarios
  - Collaboration with stakeholders





City

Monitoring

KPI

Digital Twin Models & Data

Predictions, Anomaly Detection, Analysis, Assessment Warning

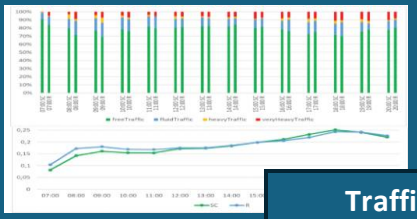
Decision Support System

Scenarious

Simulations, TFR, Crossroad, Public Transport, Routing, ..

What-If Analysis, Optimization

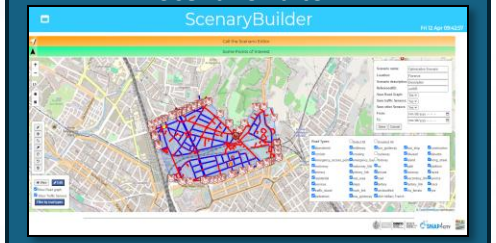
KPI, Predictions, ...



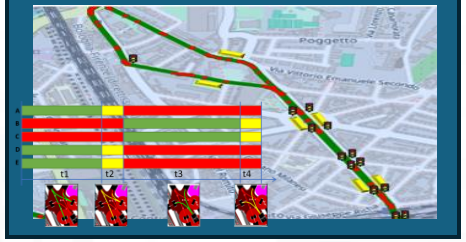
Traffic Reconstruction



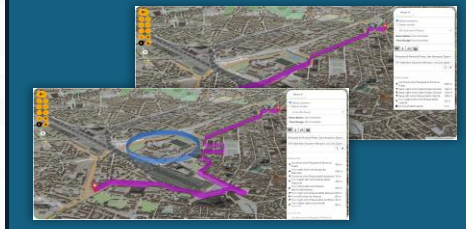
Scenario Editor



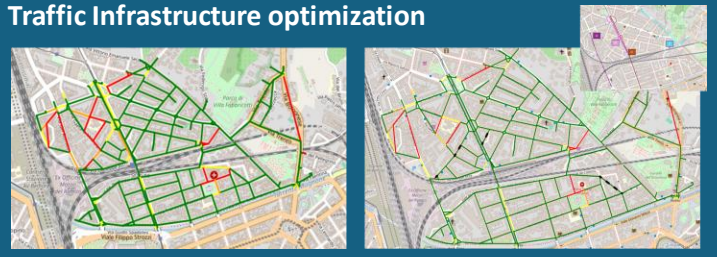
Traffic Light Plan optimization



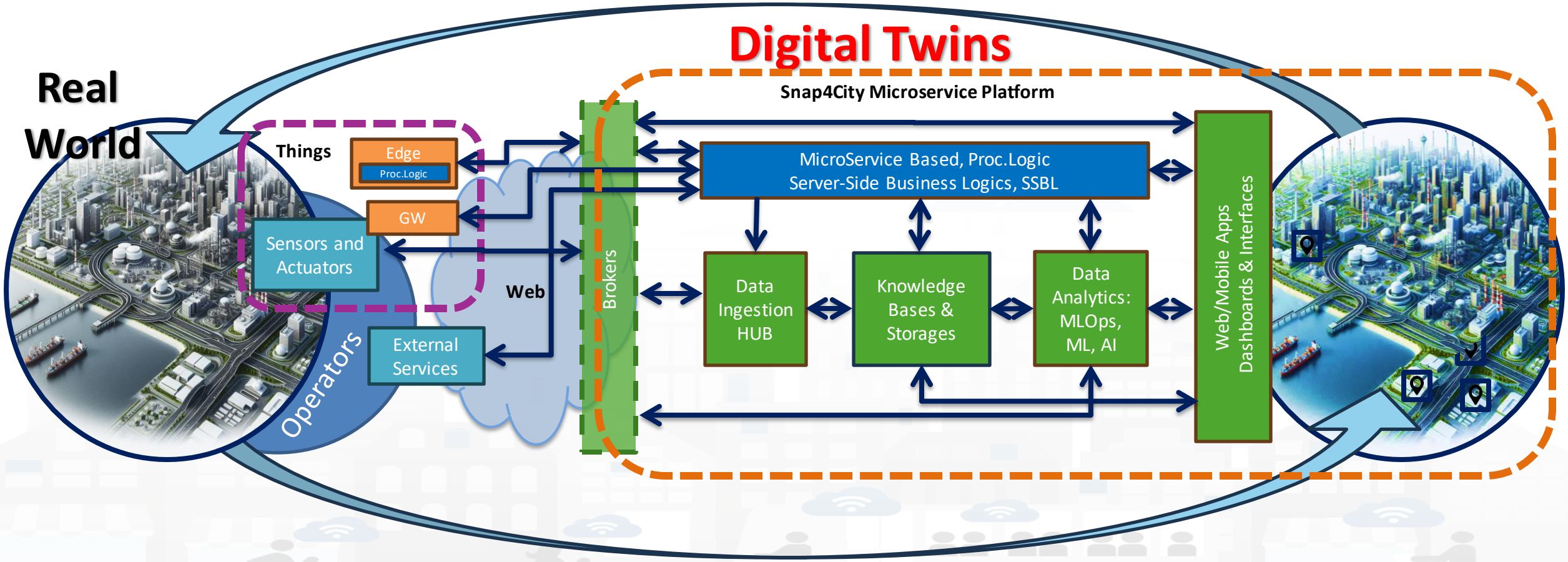
Routing / Dynamic Routing



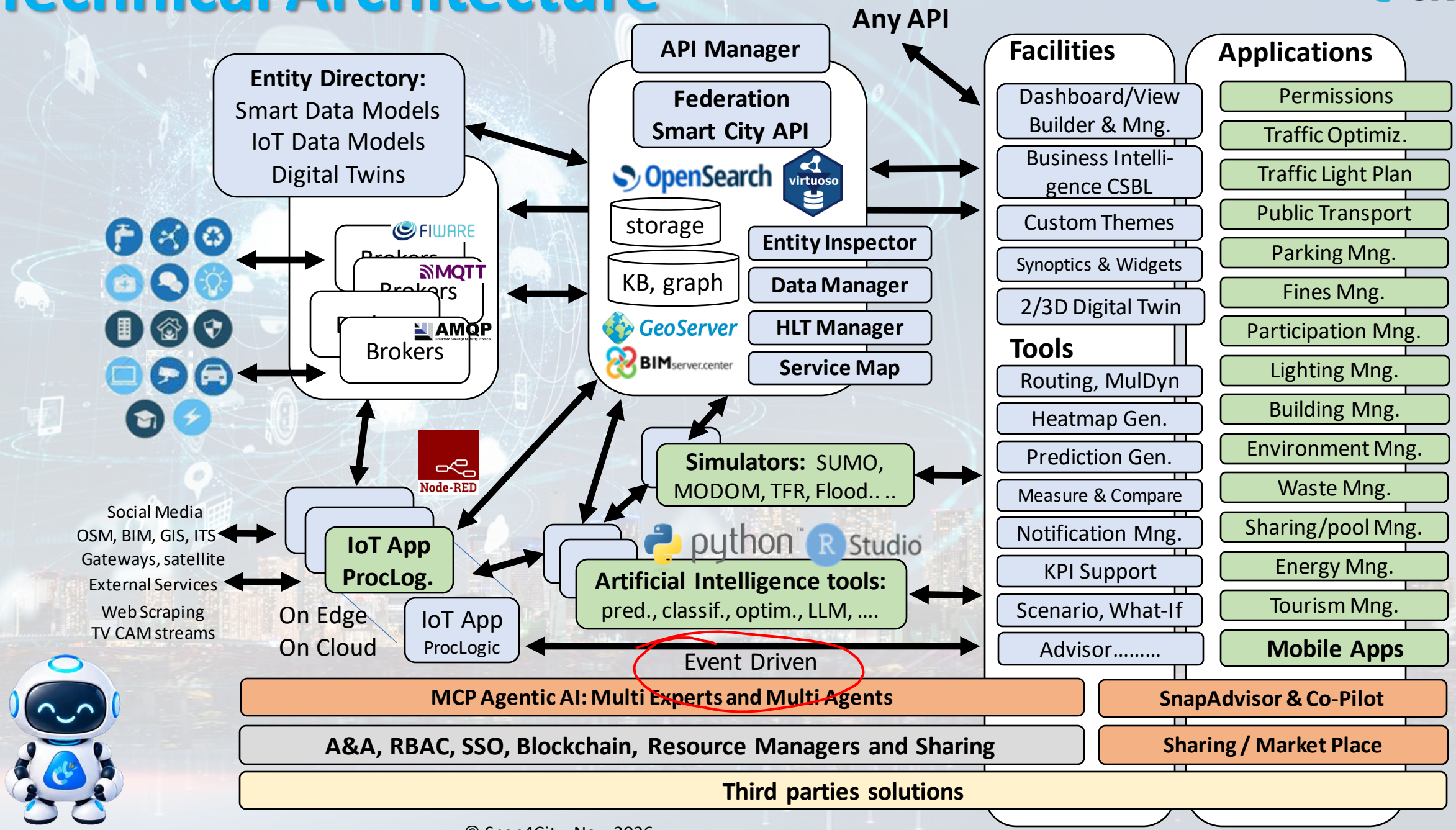
Traffic Infrastructure optimization



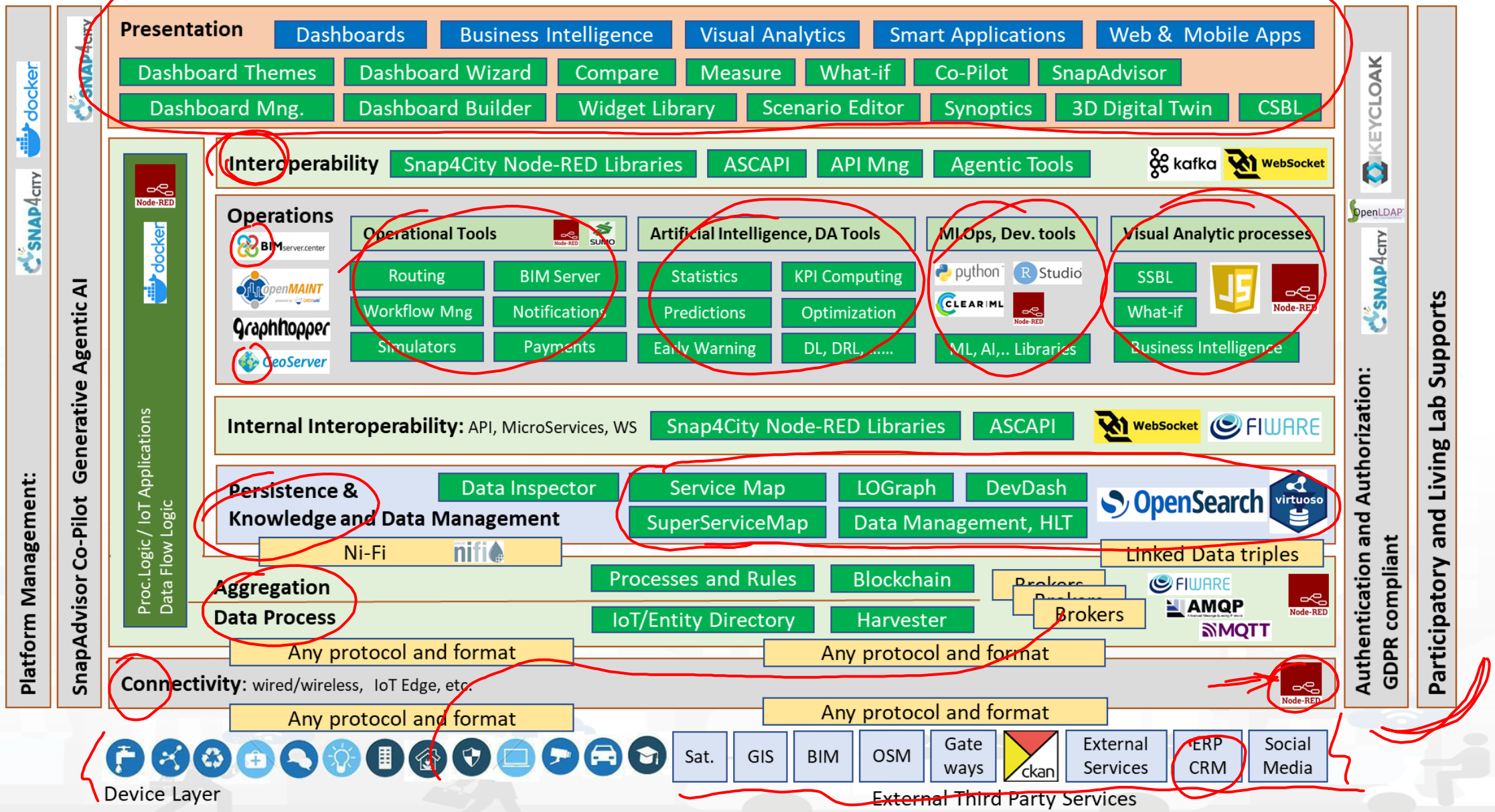
Digital Twin Development Platform

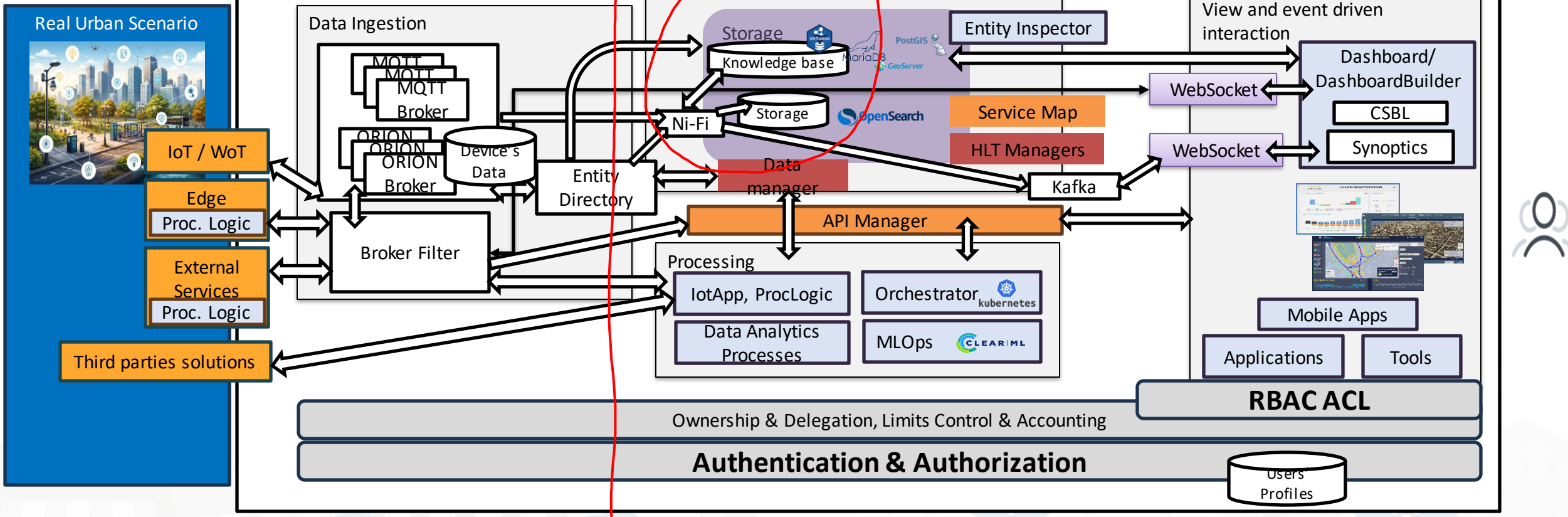


Technical Architecture

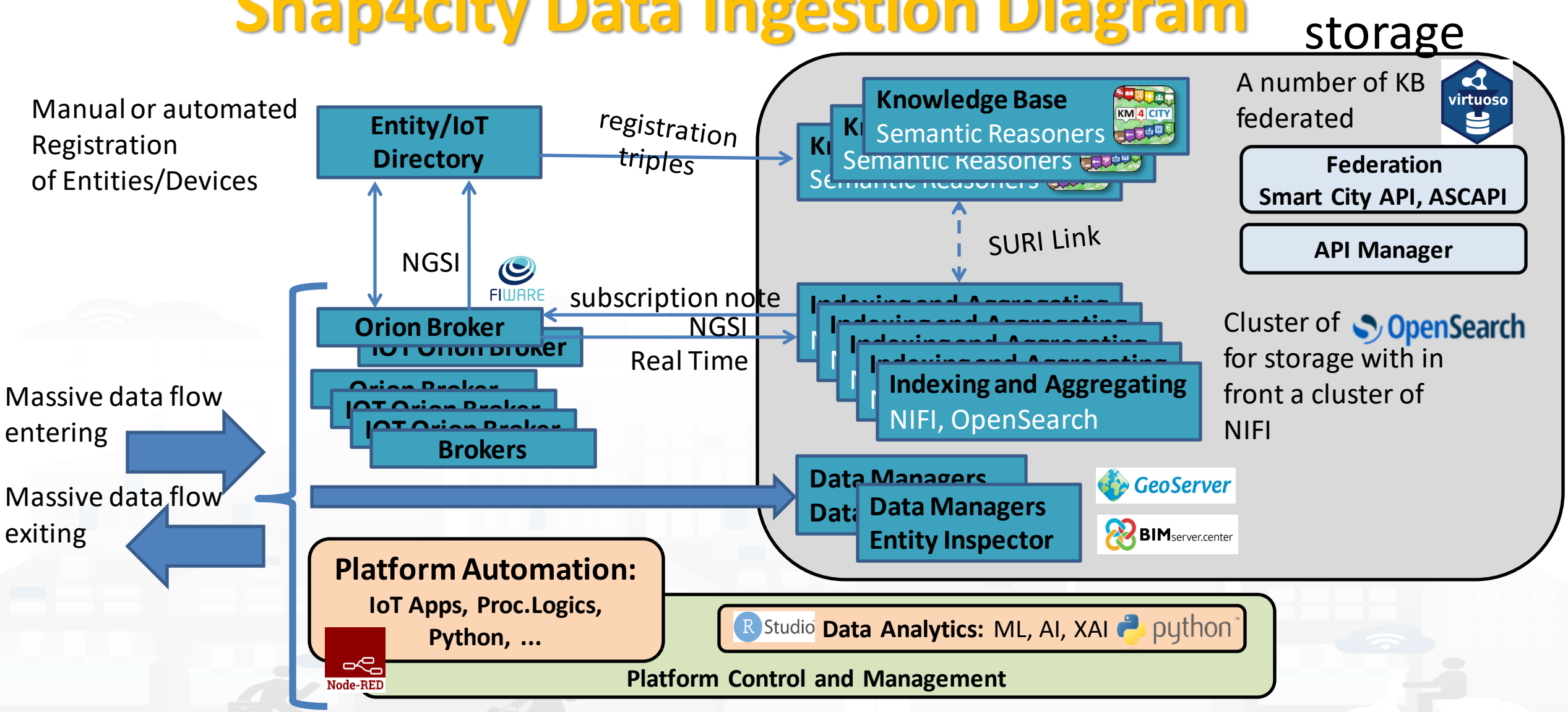


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Platform Management:
SnapAdvisor Co-Pilot Generative Agentic AI
Presentation
Dashboards
Business Intelligence
Visual Analytics
Smart Applications
Web & Mobile Apps
Dashboard Themes
Dashboard Wizard
Compare
Measure
What-if
Co-Pilot
SnapAdvisor
Dashboard Mng.
Dashboard Builder
Widget Library
Scenario Editor
Synoptics
3D Digital Twin
CSBL
Interoperability
Snap4City Node-RED Libraries
ASCAPI
API Mng
Agentic Tools
kafka
WebSocket
Operations
Operational Tools
Routing
BIM Server
Workflow Mng
Notifications
Simulators
Payments
Artificial Intelligence, DA Tools
Statistics
KPI Computing
Predictions
Optimization
Early Warning
DL, DRL, ...
MLOps, Dev. tools
ML, AI,.. Libraries
Visual Analytic processes
SSBL
What-if
Business Intelligence
Proc.Logic / IoT Applications Data Flow Logic
Internal Interoperability: API, MicroServices, WS
Snap4City Node-RED Libraries
ASCAPI
WebSocket
FIWARE
Persistence & Knowledge and Data Management
Data Inspector
Service Map
LOGraph
DevDash
SuperServiceMap
Data Management, HLT
OpenSearch
virtuoso
Linked Data triples
Ni-Fi
nifi
Aggregation Data Process
Processes and Rules
Blockchain
IoT/Entity Directory
Harvester
Brokers
FIWARE
AMQP
MQTT
Any protocol and format
Any protocol and format
Connectivity: wired/wireless, IoT Edge, etc.
Any protocol and format
Any protocol and format
Device Layer
Sat.
GIS
BIM
OSM
Gate ways
ckan
External Services
ERP CRM
Social Media
External Third Party Services
Authentication and Authorization: GDPR compliant
KEYCLOAK
OpenLDAP
Participatory and Living Lab Supports


Real Urban Scenario
IoT / WoT
Edge
Proc. Logic
External Services
Proc. Logic
Third parties solutions
Data Ingestion
MQTT Broker
ORION Broker
Device's Data
Broker Filter
Entity Directory
Digital Twin
Storage
Knowledge base
Storage
Ni-Fi
Data manager
Entity Inspector
Service Map
HLT Managers
Kafka
API Manager
Processing
IotApp, ProcLogic
Orchestrator
kubernetes
Data Analytics Processes
MLOps
CLEARML
View and event driven interaction
WebSocket
WebSocket
Dashboard/ DashboardBuilder
CSBL
Synoptics
Mobile Apps
Applications
Tools
RBAC ACL
Ownership & Delegation, Limits Control & Accounting
Authentication & Authorization
Users' Profiles

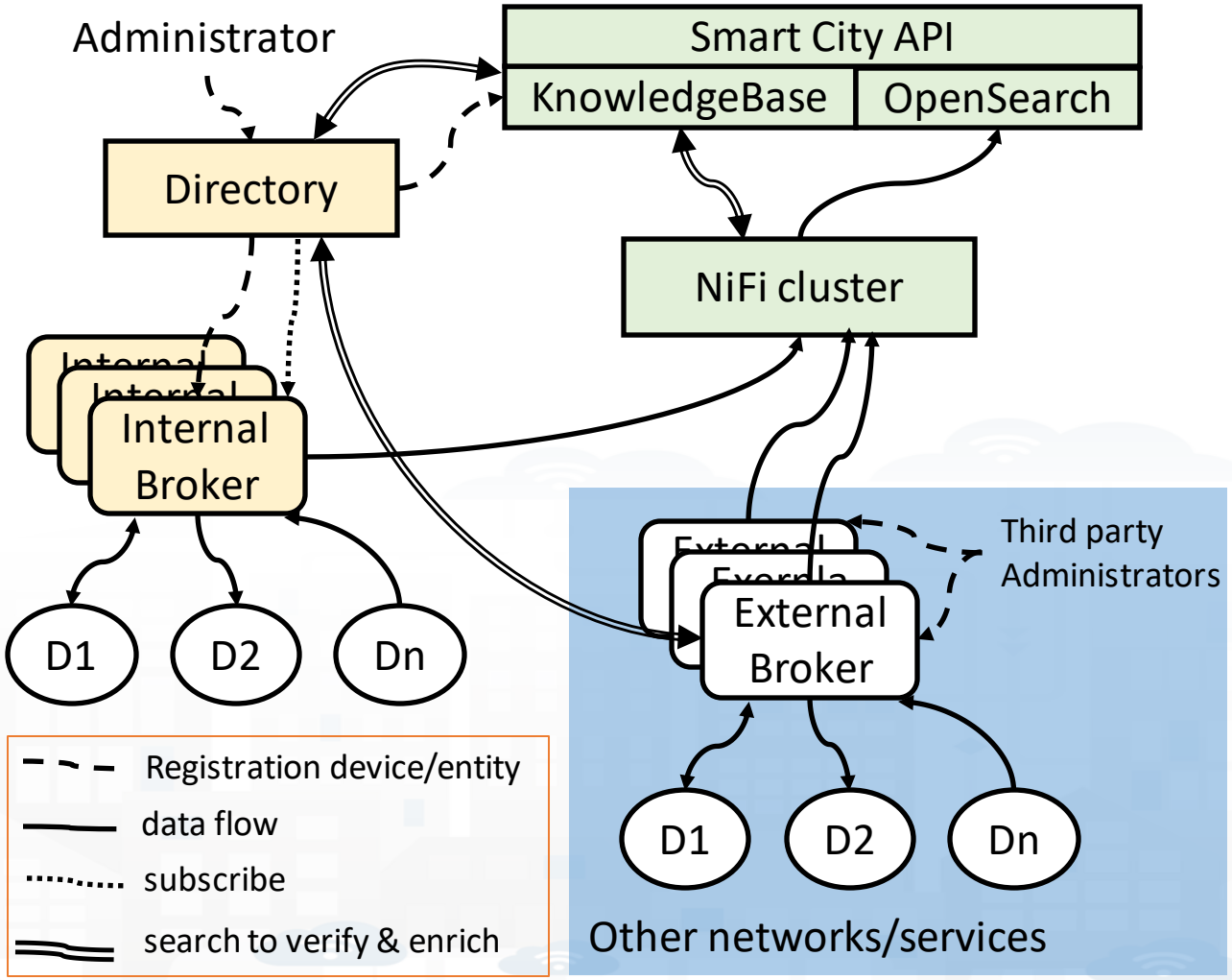
Snap4city Data Ingestion Diagram

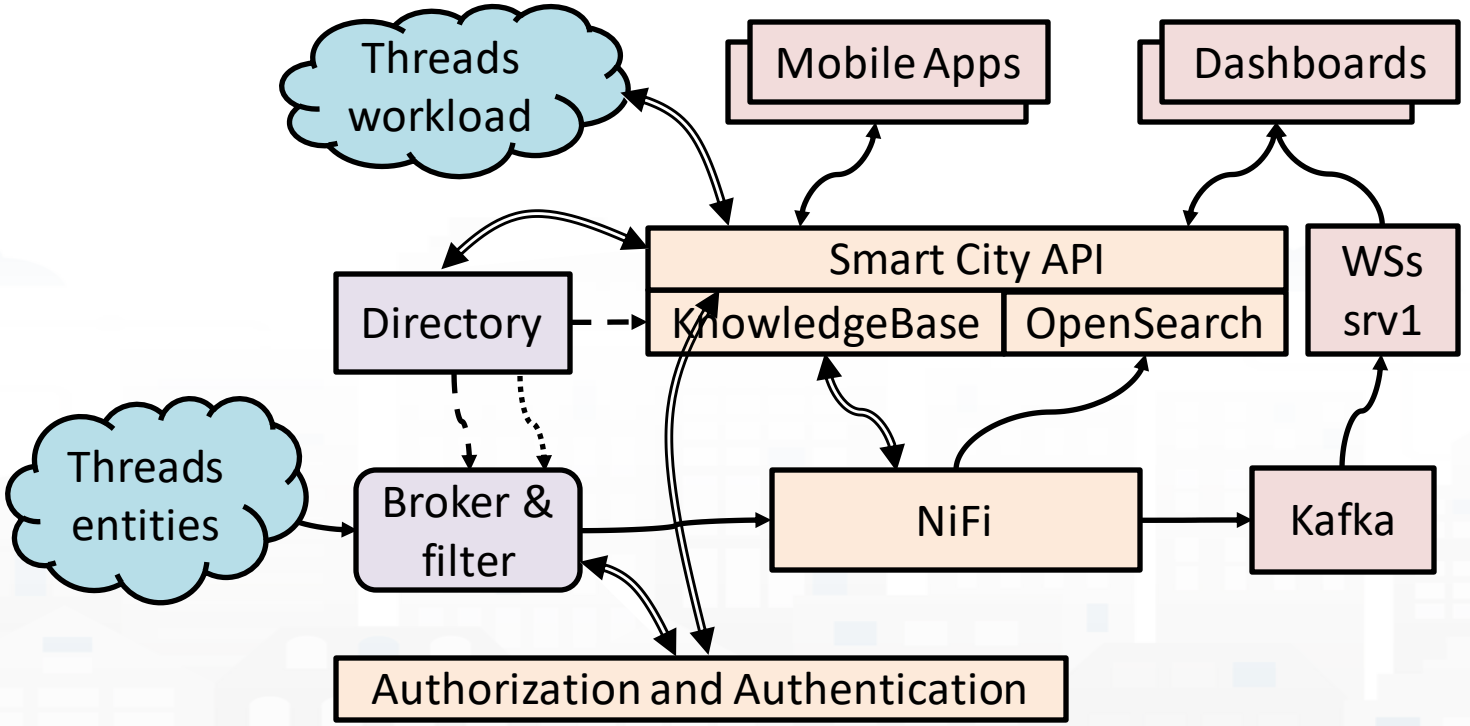


- Solr
- Kibana, grafana, banana: VI
  - Time series, drill up, dunots, etc. No maps e no HLT
- Elastic search as Indexing / database
- ES dash as VI
- Not enough ma good solo per certi tipi di dati
- Ci sono vari HLT che vanno gestiti

- KB possono avere sparql coin dentro segmenti di query SQL o cghe altro anche ES
- Possono fare da indice a KB ma anche a ES ed altri db
- Ci possiamo mettere una API specifica che mappa questi duye mondi

- I broker scalano orizz
- I broker possono essere messi dietro un balancer ma occhio alla registrazione dei device
- AMQP permette di fare questo


Administrator
Smart City API
KnowledgeBase
OpenSearch
Directory
NiFi cluster
Internal Broker
D1
D2
Dn
External Broker
Third party Administrators
D1
D2
Dn
Other networks/services
Registration device/entity
data flow
subscribe
search to verify & enrich


Threads workload
Mobile Apps
Dashboards
Smart City API
KnowledgeBase
OpenSearch
WSs srv1
Directory
Threads entities
Broker & filter
NiFi
Kafka
Authorization and Authentication

- Tanti broker su un unico nifi…. No allora nifi federato
- Nifi arricchisce con KB e IOT directory
- E invia a OS

APACHE NIFI / ELABORAZIONE DISTRIBUITA

Un solo flusso, eseguito su tutti i nodi

La definizione del flusso è comune. Ogni nodo elabora i FlowFile presenti nelle proprie code.

INGRESSO DATI DISTRIBUITO
Esempio: Site-to-Site oppure un ingresso HTTP dietro bilanciatore

Lotto A | Lotto B | Lotto C

NODO NIFI 1 / VM
STESSO FLUSSO · VERSIONE v1
01 Valida dati
coda locale
02 Trasforma dati
coda locale
03 Invia a OpenSearch
FlowFile del lotto A · repository locali

NODO NIFI 2 / VM
STESSO FLUSSO · VERSIONE v1
01 Valida dati
coda locale
02 Trasforma dati
coda locale
03 Invia a OpenSearch
FlowFile del lotto B · repository locali

NODO NIFI 3 / VM
STESSO FLUSSO · VERSIONE v1
01 Valida dati
coda locale
02 Trasforma dati
coda locale
03 Invia a OpenSearch
FlowFile del lotto C · repository locali

CLUSTER OPENSEARCH
Tutti i nodi scrivono verso la stessa destinazione logica.

COORDINAMENTO DEL CLUSTER
ZooKeeper supporta elezioni e stato condiviso.
Il Cluster Coordinator monitora i nodi.
Le code e i contenuti non sono replicati tra i nodi.

ECCEZIONE: "PRIMARY NODE ONLY"
Un processore con questa impostazione viene eseguito soltanto sul nodo primario eletto.
Gli altri processori possono lavorare su tutti i nodi.

Schema di esempio: la distribuzione dei dati dipende dai processori e dalle politiche di bilanciamento configurate.



APACHE ZOOKEEPER / COORDINAMENTO DI NIFI

ZooKeeper coordina il cluster NiFi

Gestisce informazioni di coordinamento; i dati applicativi vengono elaborati dai nodi NiFi.

ENSEMBLE ZOOKEEPER · 3 VM

Un leader interno coordina le scritture; i follower mantengono lo stato replicato.

ZooKeeper 1	ZooKeeper 2	ZooKeeper 3
Leader interno	Follower	Follower

QUORUM: servono 2 server su 3 per confermare le modifiche

Elezione dei ruoli NiFi + stato condiviso dei processori

CLUSTER NIFI · ESEMPIO DI RUOLI ELETTI

NODO NIFI 1
Cluster Coordinator
Monitora salute e appartenenza
Elabora anche il flusso comune

NODO NIFI 2
Primary Node
Esegue i processori "Primary only"
Elabora anche il flusso comune

NODO NIFI 3
Nodo di elaborazione
Processori configurati "All nodes"
Elabora anche il flusso comune

Gli heartbeat dei nodi vanno al Cluster Coordinator. I due ruoli eletti possono essere sullo stesso nodo.

SE UN SERVER ZOOKEEPER SI FERMA

Restano 2 su 3: il quorum è disponibile.

Il servizio può continuare; se necessario viene eletto un nuovo leader interno a ZooKeeper.

SE SI FERMANO DUE SERVER ZOOKEEPER

Resta 1 su 3: manca il quorum.

Nuove elezioni e aggiornamenti dello stato condiviso non sono disponibili.

Da ricordare: il leader ZooKeeper è diverso dal Primary Node e dal Cluster Coordinator di NiFi.

ZooKeeper non conserva i contenuti dei FlowFile, non replica le code NiFi e non bilancia il traffico dati.

OpenSearch: cluster, shard e repliche

Un indice si divide in shard. Le repliche mantengono copie su nodi diversi.

ESEMPIO: INDICE "EVENTI"

3 shard primari + 1 replica per shard = 6 copie

Nodo 1	Nodo 2	Nodo 3
P0	P1	P2
R2	R0	R1

P0 e R0 contengono gli stessi documenti.

P0, P1 e P2 contengono porzioni diverse dell'indice.
Ogni coppia primario/replica risiede su nodi distinti.

SCRITTURA

Il nodo coordinatore instrada il documento al primario corretto. Il primario aggiorna le repliche.

RICERCA

La query usa una copia per ogni shard coinvolto. Il coordinatore raccoglie e combina i risultati.

GUASTO DI UN NODO

Se il Nodo 1 si ferma, R0 sul Nodo 2 può diventare P0. Il cluster ricrea le copie mancanti dove possibile.

Shard: distribuiscono i dati e il lavoro. Repliche: aumentano resilienza e capacità di lettura.

Esempio con repliche ordinarie. Il failover richiede copie aggiornate e quorum dei cluster manager, non mostrati.

01 / FEDERATED INGESTION · SHARED SEARCH PLATFORM

Apache NiFi + OpenSearch

Two sites • Independent NiFi clusters • One OpenSearch cluster with dedicated search nodes

SITE A

WRITE PATH

Apache NiFi · 3 worker VMs
Persistent queues + retry / replay

ZooKeeper · 3 VMs
NiFi coordination only

HTTPS bulk writes

OpenSearch · 3 data VMs
Primary shards + ordinary replicas • SSD-backed storage

READ PATH

Applications
Local HA endpoint
Optional coordinators

→

2 search VMs
Search-only shard copies
Scale independently

SITE B

WRITE PATH

Apache NiFi · 3 worker VMs
Persistent queues + retry / replay

ZooKeeper · 3 VMs
NiFi coordination only

HTTPS bulk writes

OpenSearch · 3 data VMs
Primary shards + ordinary replicas • SSD-backed storage

READ PATH

Applications
Local HA endpoint
Optional coordinators

→

2 search VMs
Search-only shard copies
Scale independently

REMOTE-BACKED STORAGE

Data primaries upload segments and translogs; replicas retrieve segments.

Required for this dedicated-search design. Validate storage resilience, connectivity and search freshness.

OPENSEARCH CONTROL PLANE

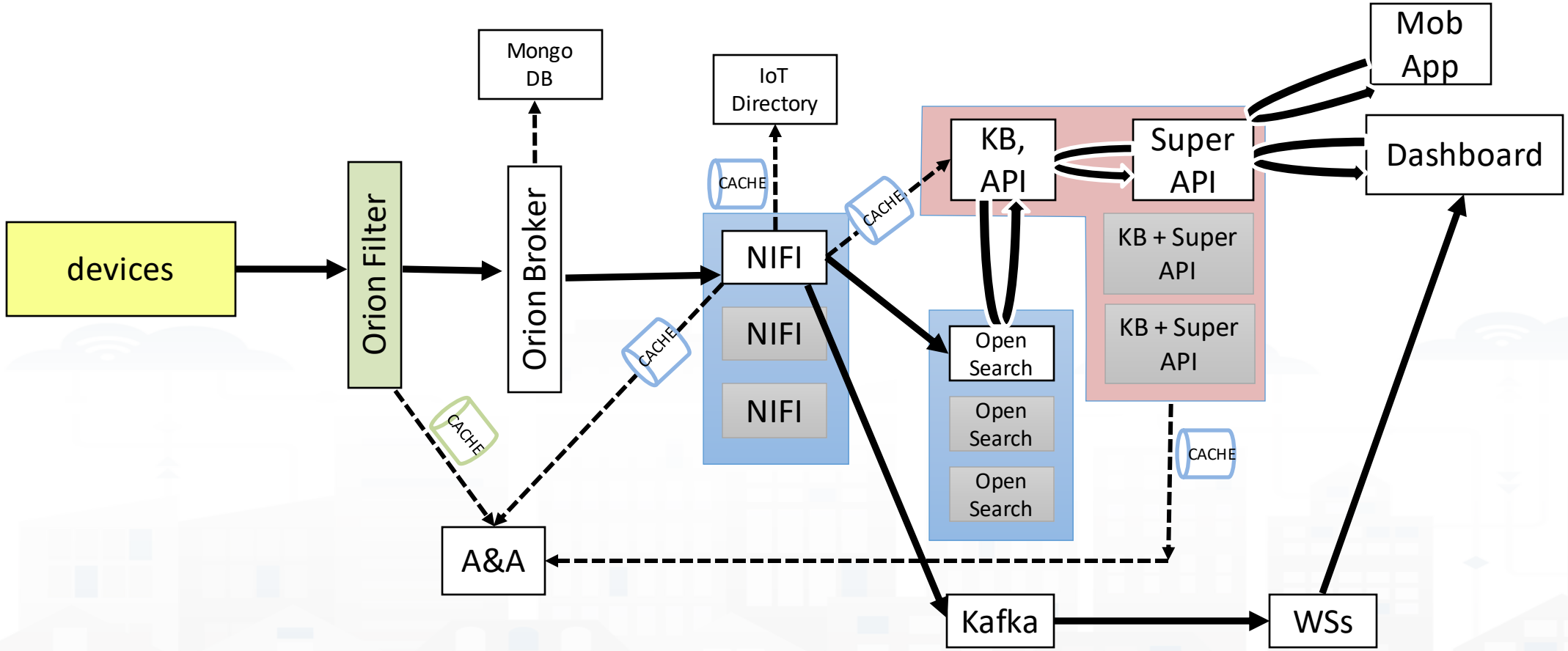
Manager A · 1 VM
Site A

Manager C · 1 VM
Independent third location

Manager B · 1 VM
Site B

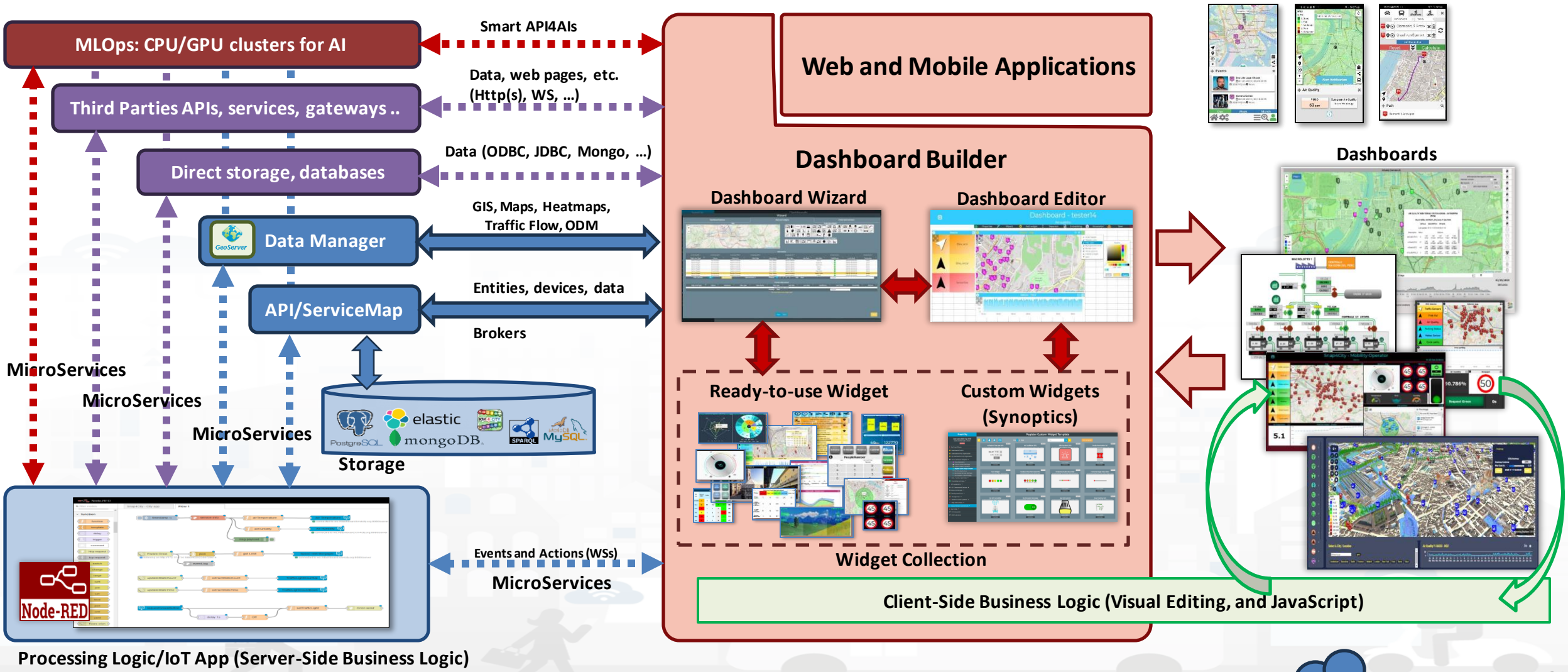
2 of 3 managers for quorum • Site-aware shard placement • Each site sized for the required failover load

Conceptual design: validate OpenSearch version and remote-store support before implementation.

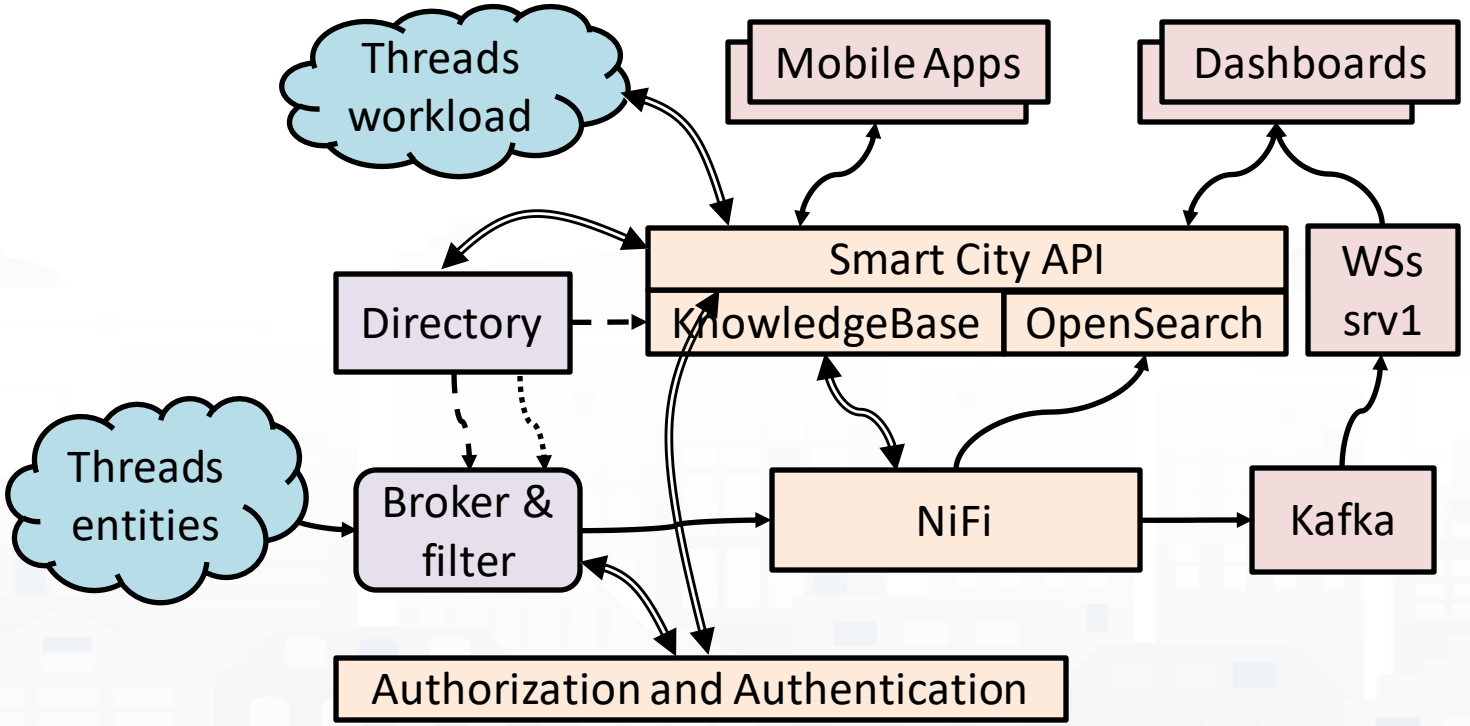

devices
Orion Filter
Orion Broker
Mongo DB
IoT Directory
CACHE
NIFI
NIFI
NIFI
CACHE
CACHE
CACHE
KB, API
Super API
KB + Super API
KB + Super API
Open Search
Open Search
Open Search
CACHE
A&A
Kafka
WSs
Mob App
Dashboard

B

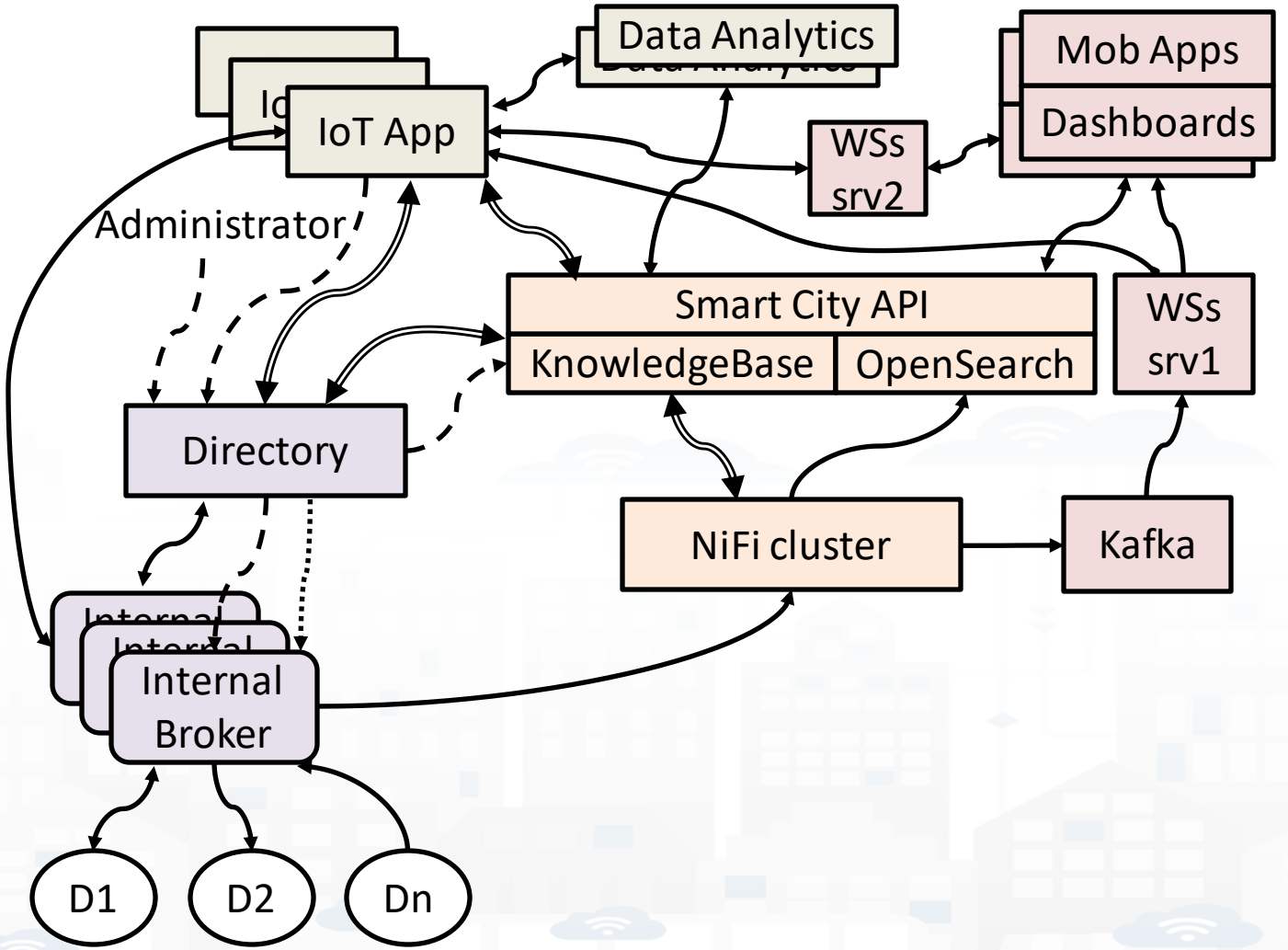
How the Dashboards / Apps Exchange data (2024/8)



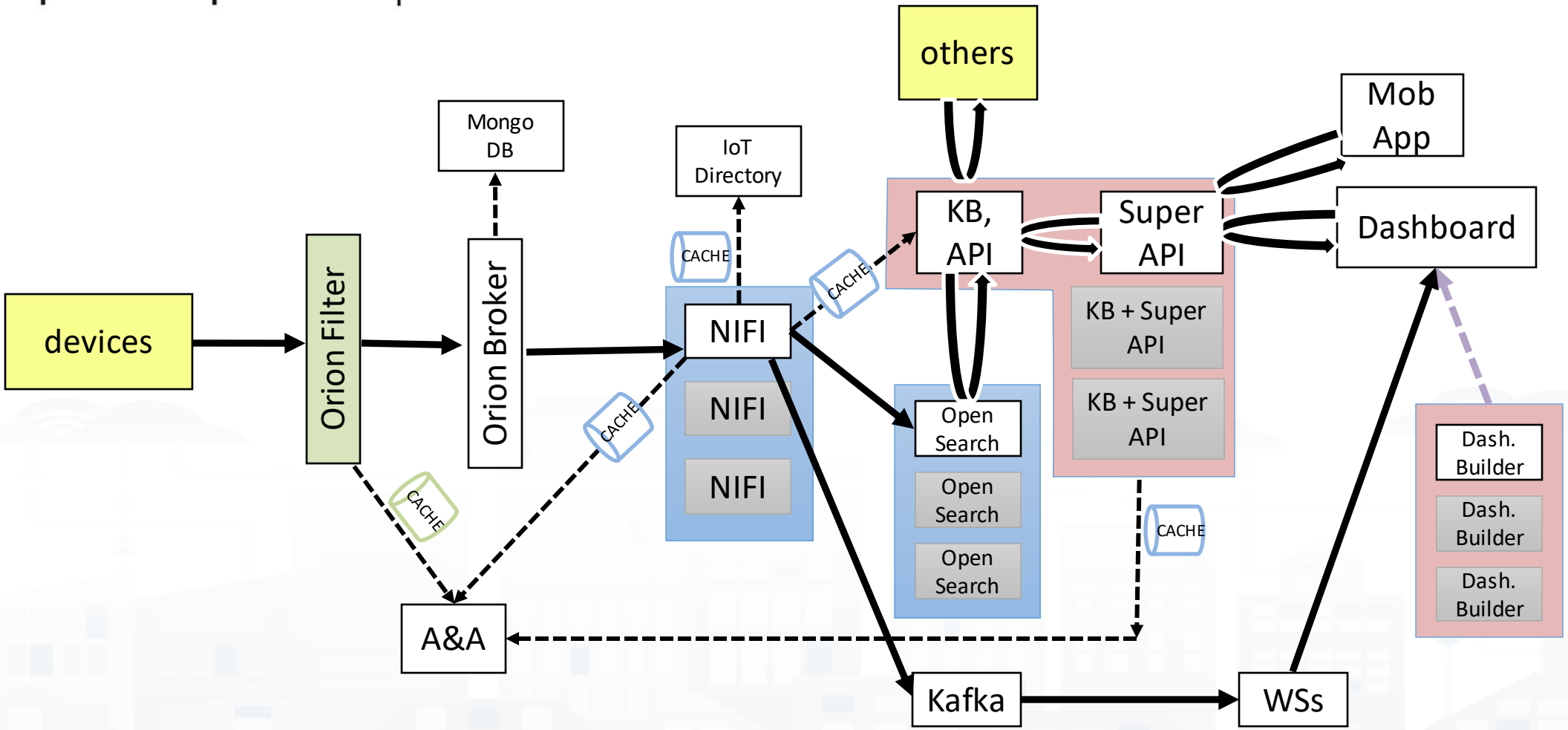
Event Driven towards end users



WS bidirectional



Registration device/entity
data flow
subscribe
search to verify & enrich


others
Mob App
Mongo DB
IoT Directory
KB, API
Super API
Dashboard
CACHE
CACHE
devices
Orion Filter
Orion Broker
NIFI
KB + Super API
NIFI
Open Search
KB + Super API
Dash. Builder
NIFI
Open Search
CACHE
CACHE
CACHE
Dash. Builder
Open Search
Dash. Builder
A&A
Kafka
WSs

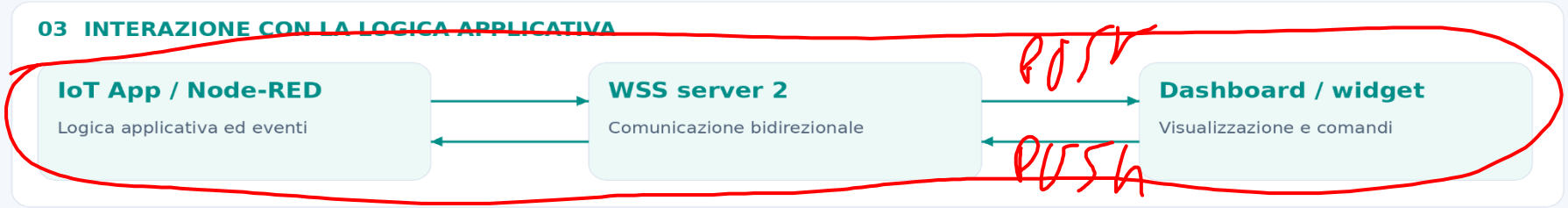
B

SNAP4CITY / DISTRIBUZIONE EVENTI AL FRONTEND

Da Kafka ai widget tramite WebSocket

Schema logico del percorso documentato: il browser riceve gli eventi dal server WSS.





Kafka gestisce il flusso interno. Il livello WSS distribuisce gli eventi alle connessioni frontend.

Autenticazione, autorizzazioni e sottoscrizioni determinano quali dati può ricevere ciascun client.

WSS = WebSocket Secure. "Server 1/2" indica i ruoli nello schema pubblicato, non un numero di VM.

Fonti: Bellini et al., Internet of Things (2023), architettura Snap4City; snap4city.org/drupal/node/738 e /888.

UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

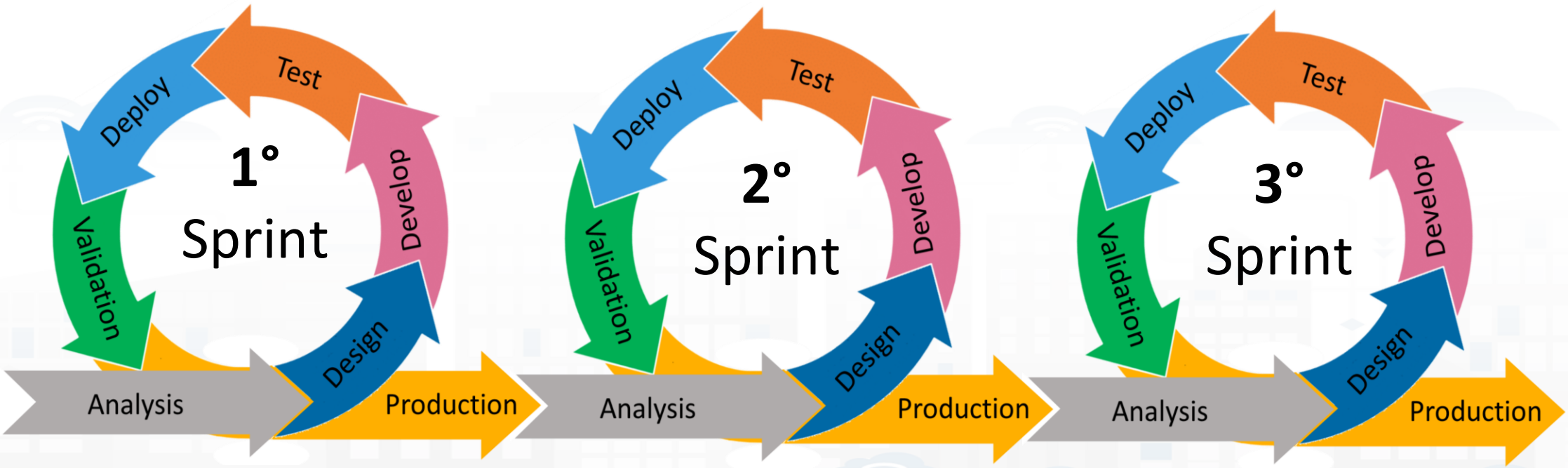
Development Life Cycle

https://www.snap4City.org **https://www.Km4City.org**

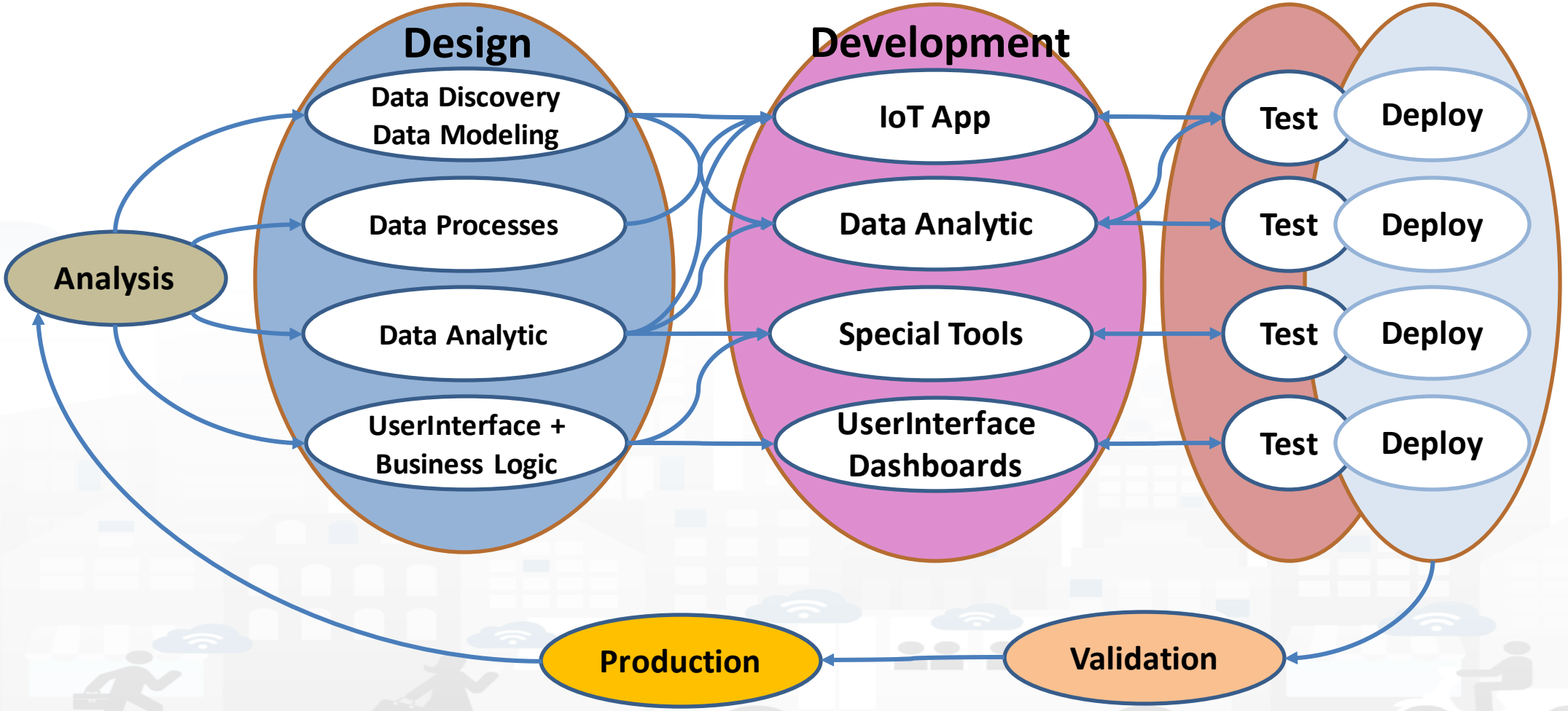


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Development Life Cycle
Smart Solutions

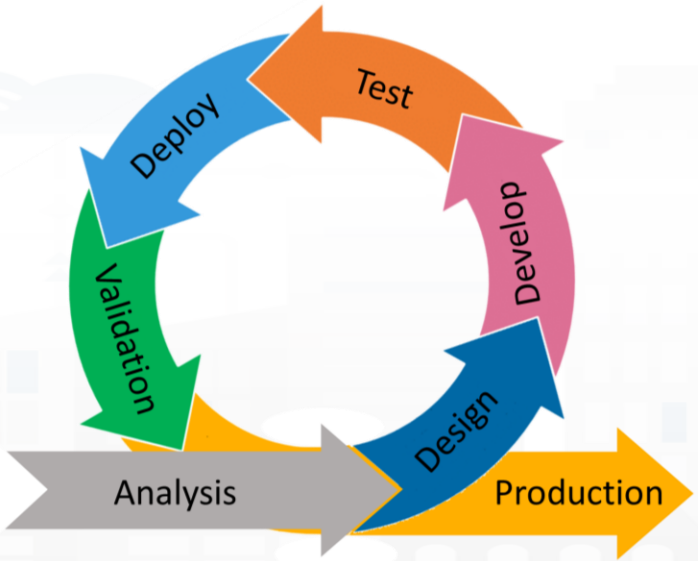


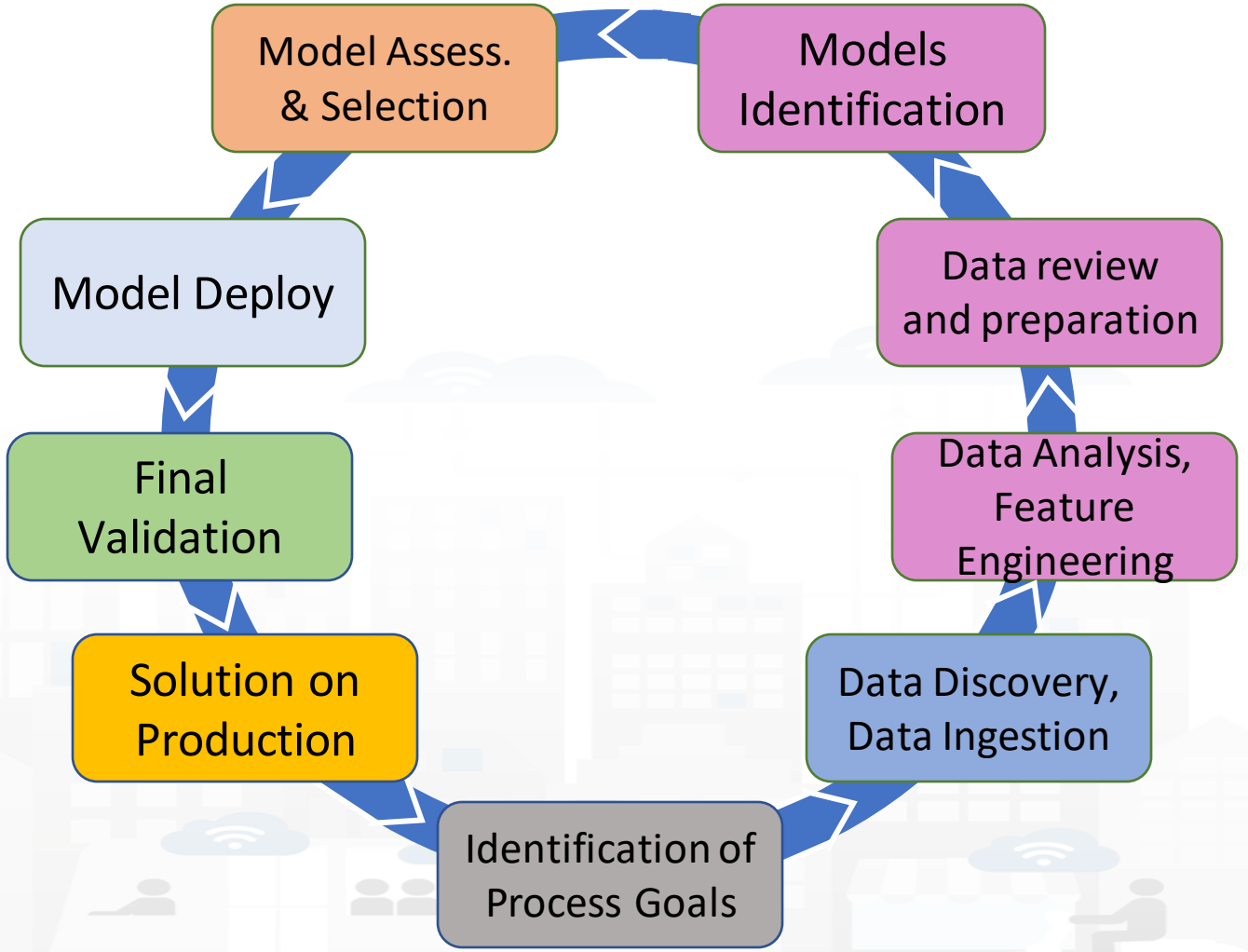
Development Life Cycle Smart Solutions



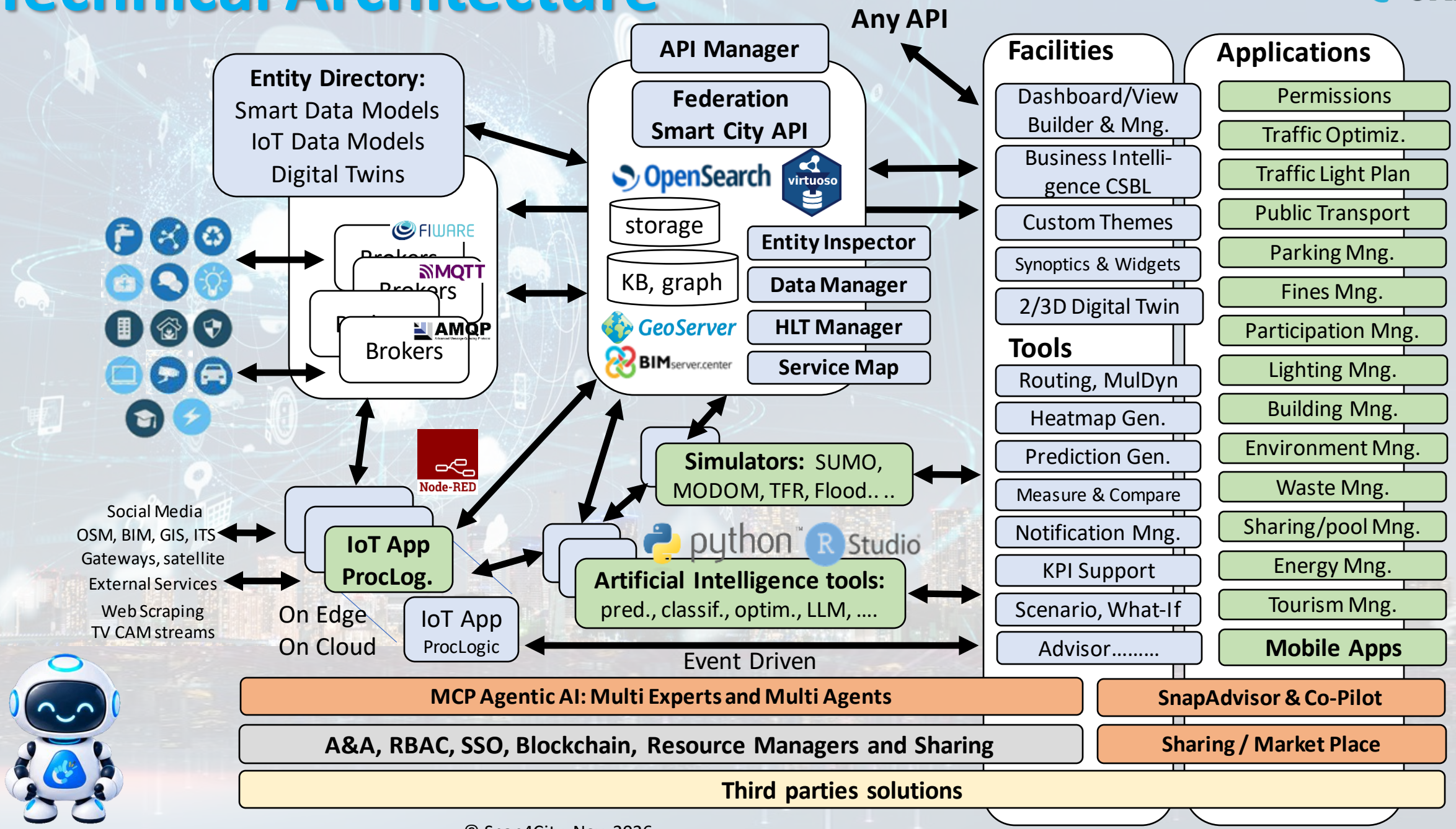
Data Analytics Development Life Cycle

- Detailed development process



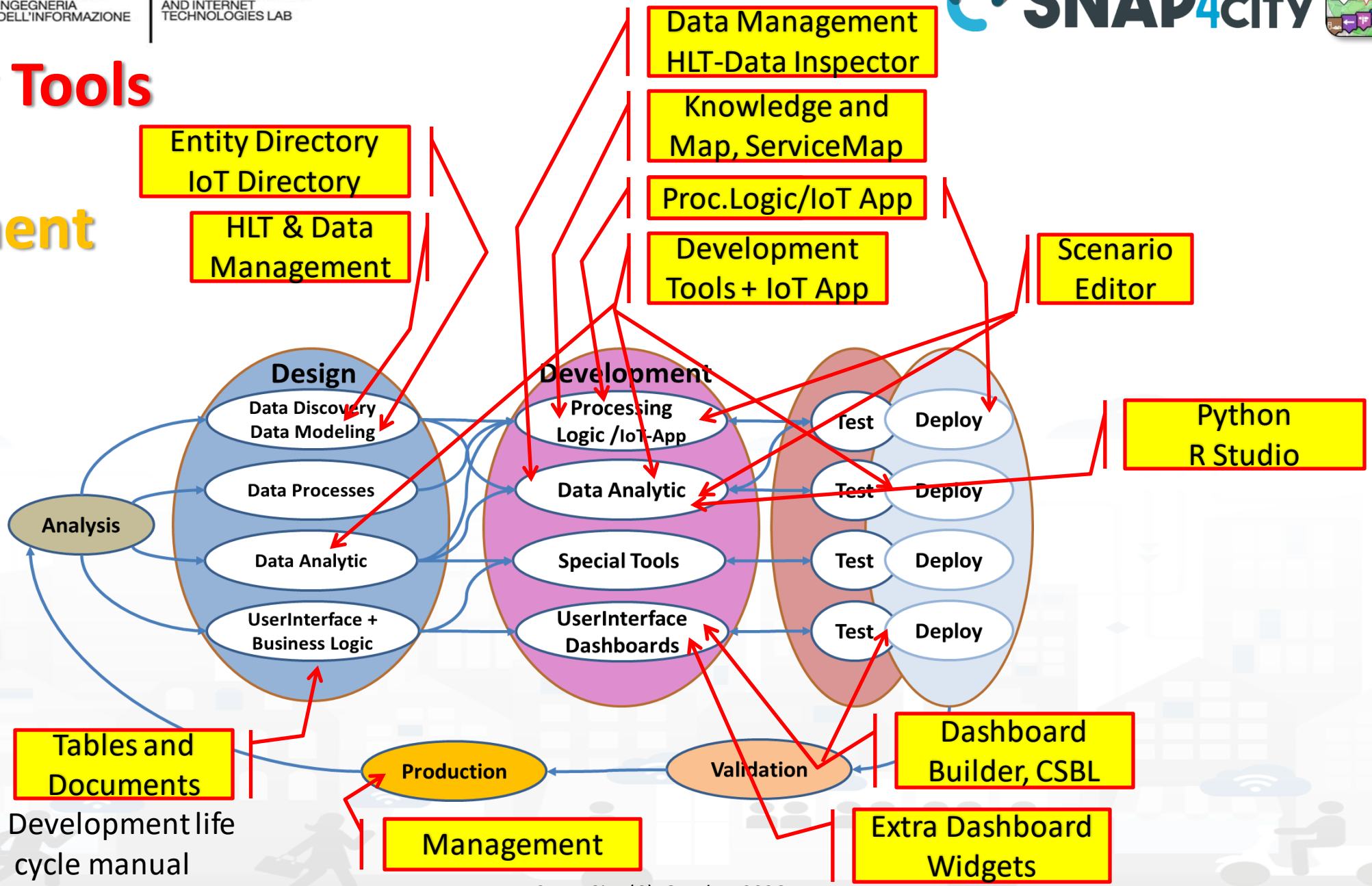


Technical Architecture



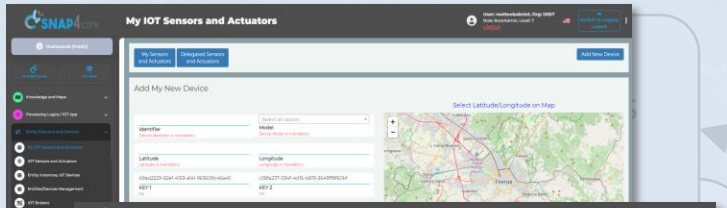
© Snap4City Nov 2026

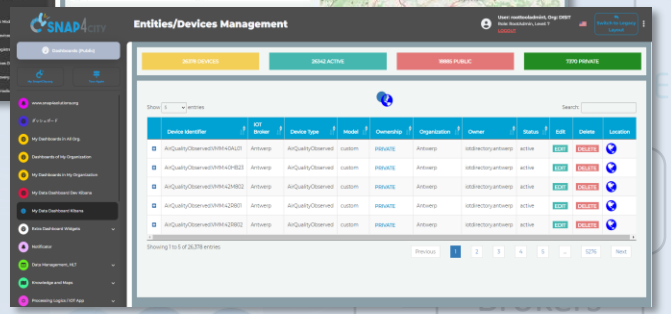
Snap4City Tools vs Development Life Cycle

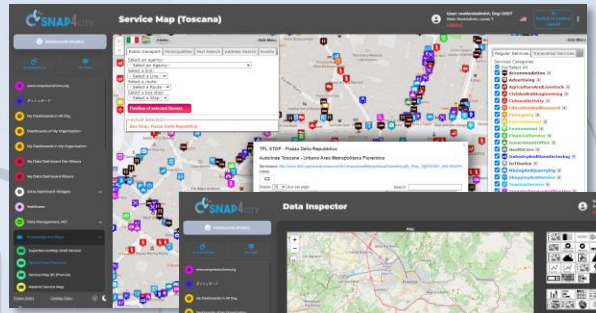


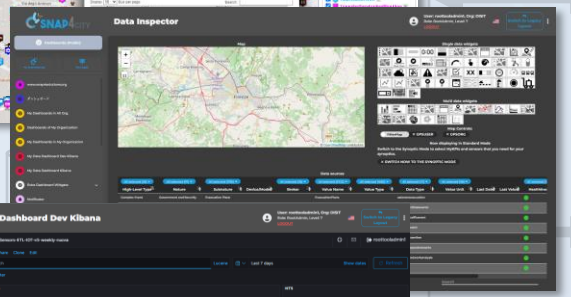
Development life cycle manual

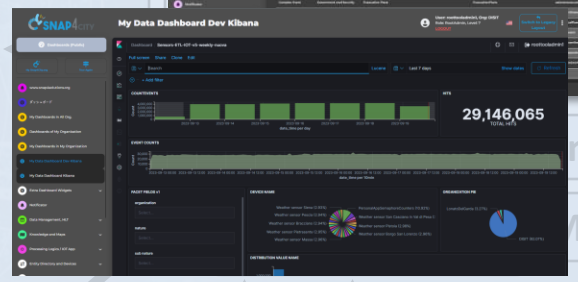
Visual Development Tools

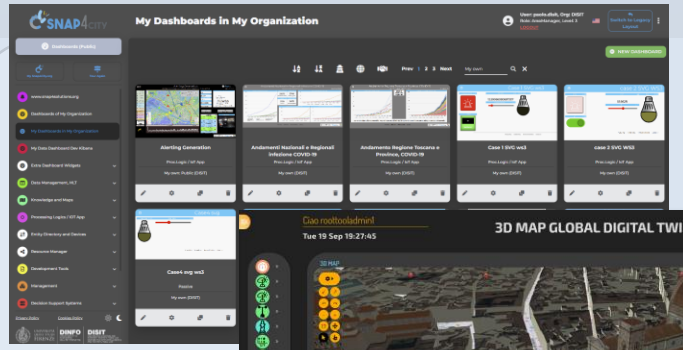




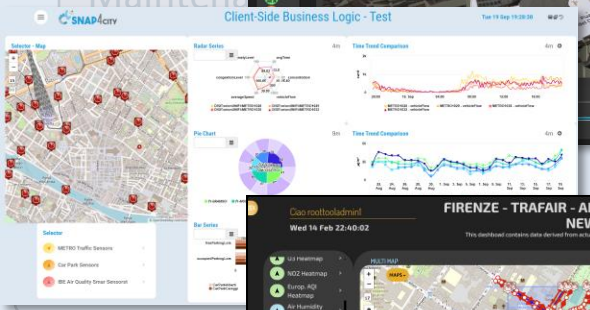


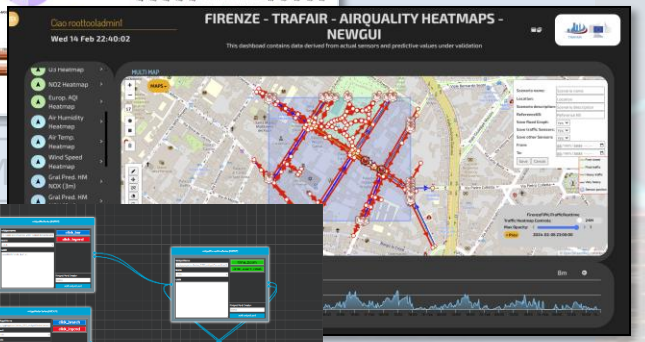


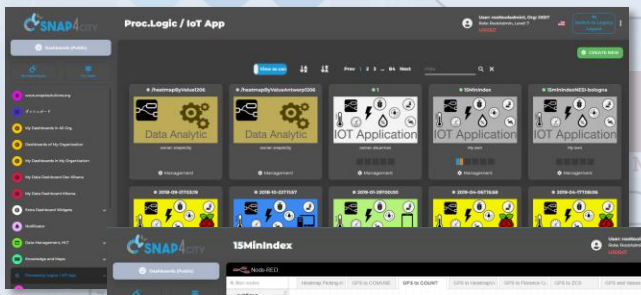


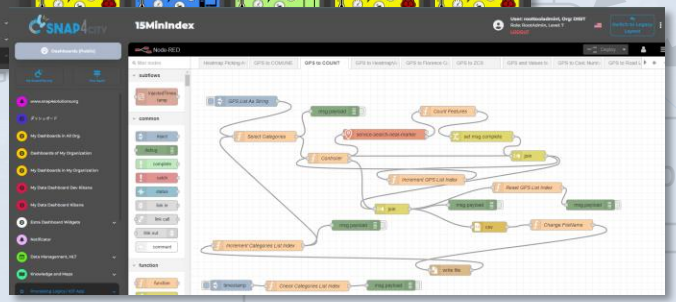


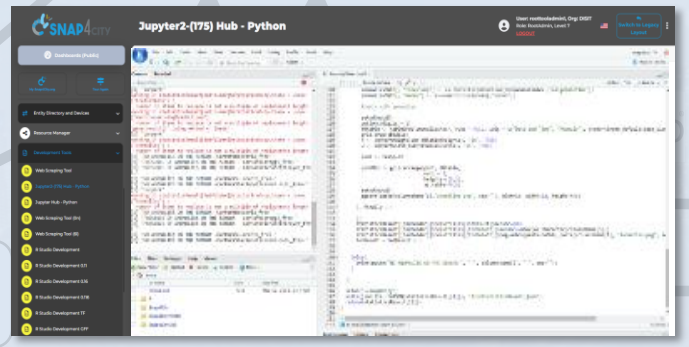


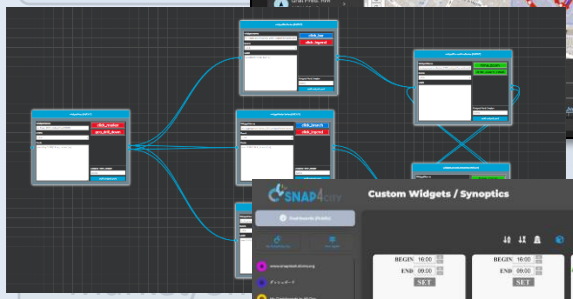














Maintena

nspector

Managers

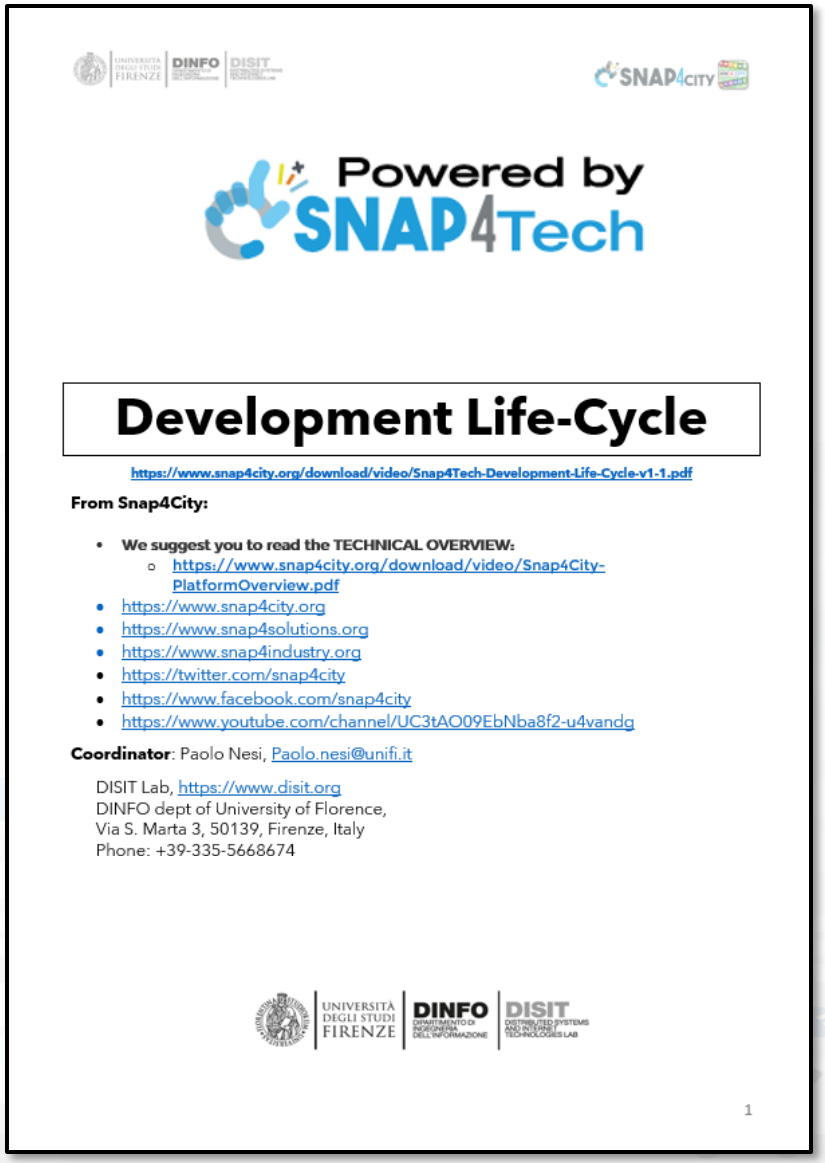
Service M

Node-RED

Third parties solutions

A&A, SSO, Blockchain, Resource Managers and Sharing: IoT App, Data Analytics

Development



Powered by SNAP4Tech

Development Life-Cycle

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle-v1-1.pdf

From Snap4City:

- **We suggest you to read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAO09EbNba8f2-u4vandg

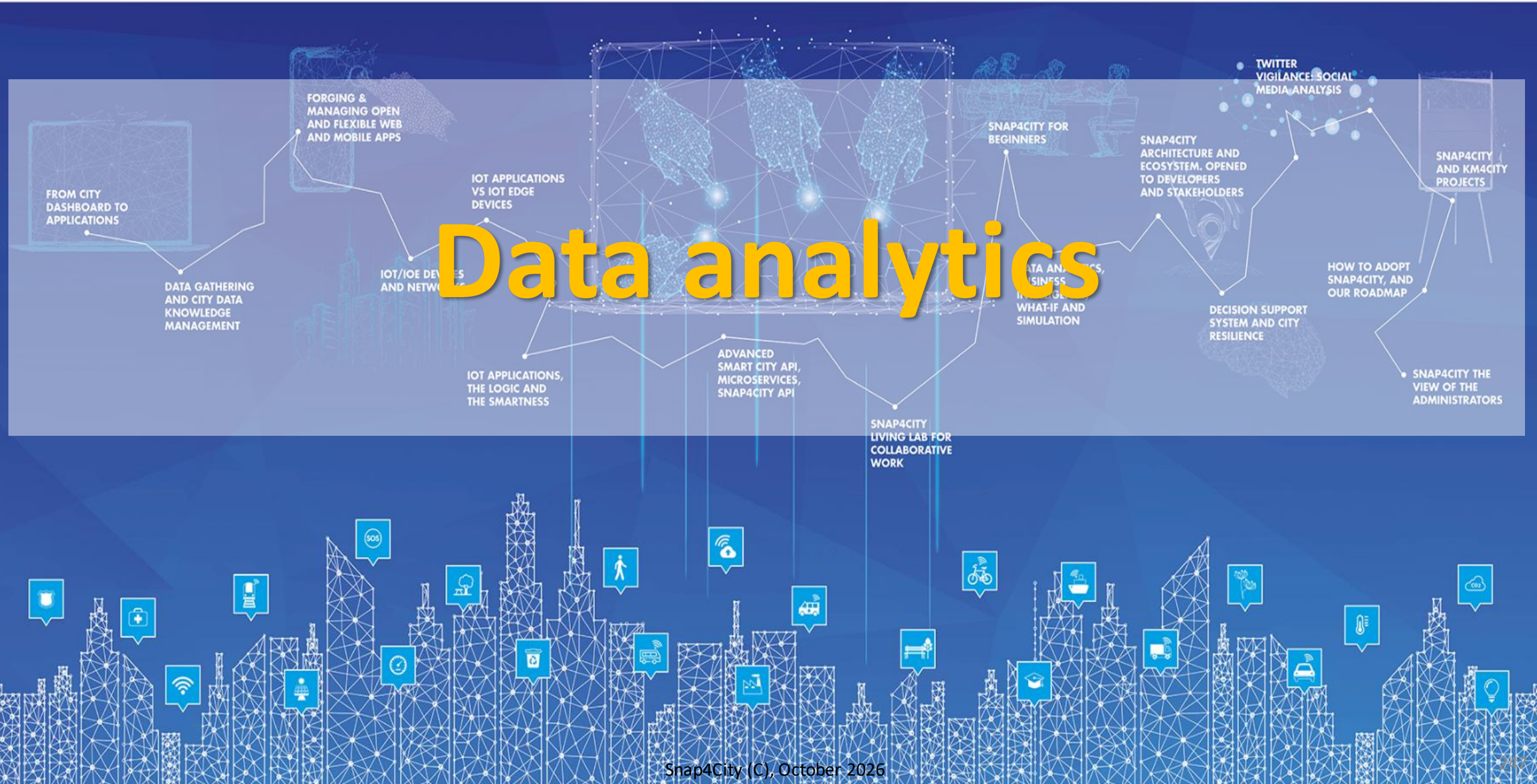
Coordinator: Paolo Nesi, Paolo.nesi@unifi.it

DISIT Lab, https://www.disit.org
DINFO dept of University of Florence,
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Phone: +39-335-5668674

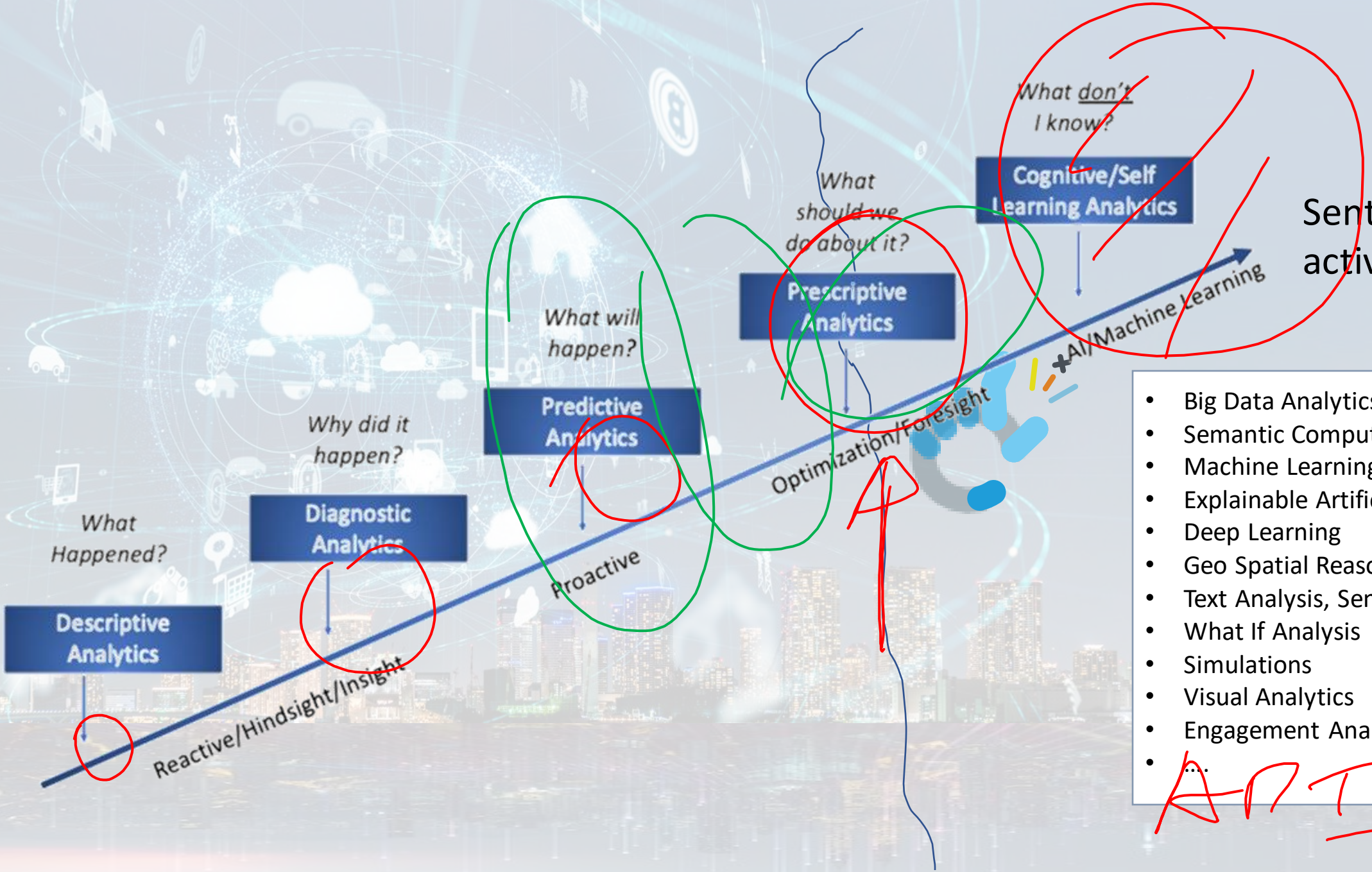
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1

https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf



Data analytics



Sentient and active processes

- Big Data Analytics
- Semantic Computing
- Machine Learning
- Explainable Artificial Intelligence
- Deep Learning
- Geo Spatial Reasoning
- Text Analysis, Sentiment Analysis
- What If Analysis
- Simulations
- Visual Analytics
- Engagement Analysis
- ….

SUSTAINABLE DEVELOPMENT GOALS

SDS

SNAP4CITY

KM 4 CITY



- ***15 Minute City Index:***
  - 13 subindexes: energy, slow mobility, fast mobility, housing, economy education, culture and cults, health, entertainment, gov, food, security…



- Optimization of car sharing/pooling
- Monitoring and Prediction of energy consumption
- Stimulating: Bike sharing, e-bikes, car charge, etc.
- Sizing energy plants, Community of energy



- Predictive maintenance
- Decisions Support Systems
- Process optimization, control
- Industry 4.0 integrated solutions
- AI assistant for commercial activities



- Reduction of emissions, reduction of congestions
- Smart City infrastructure: monitoring and resilience, long terms predictions, optim. operation and plan
- Effective and Low cost smart solutions
- What-if analysis, Simulations, optimization
- Origin Destination matrices computation



- Optimization of Waste Collection
- business intelligence tools for decision makers
- Reduction production costs
- Monitoring resource consumption
- Advisor for documentation, generative AI





- Reduction of emissions, reduction of congestions
- Monitoring and Predicting: NO2, NOX, CO2, Traffic flow, pollutant, landslide, waste, etc.
- Traffic flow reconstruction, optimisation
- Demand vs Offer of Mobility analysis



- Shortening justice time
- Prediction of mediation proneness
- Assisting institution is taking legal decisions
- Anonymization and indexing legal docs.
- Ethical Explainable Artificial Intelligence
- Advisor for legal documentation, generative AI

(9/2025)

Available AI Solutions on Snap4City

https://www.snap4city.org/997

More than 80 Available Solutions & 300 AI applic.

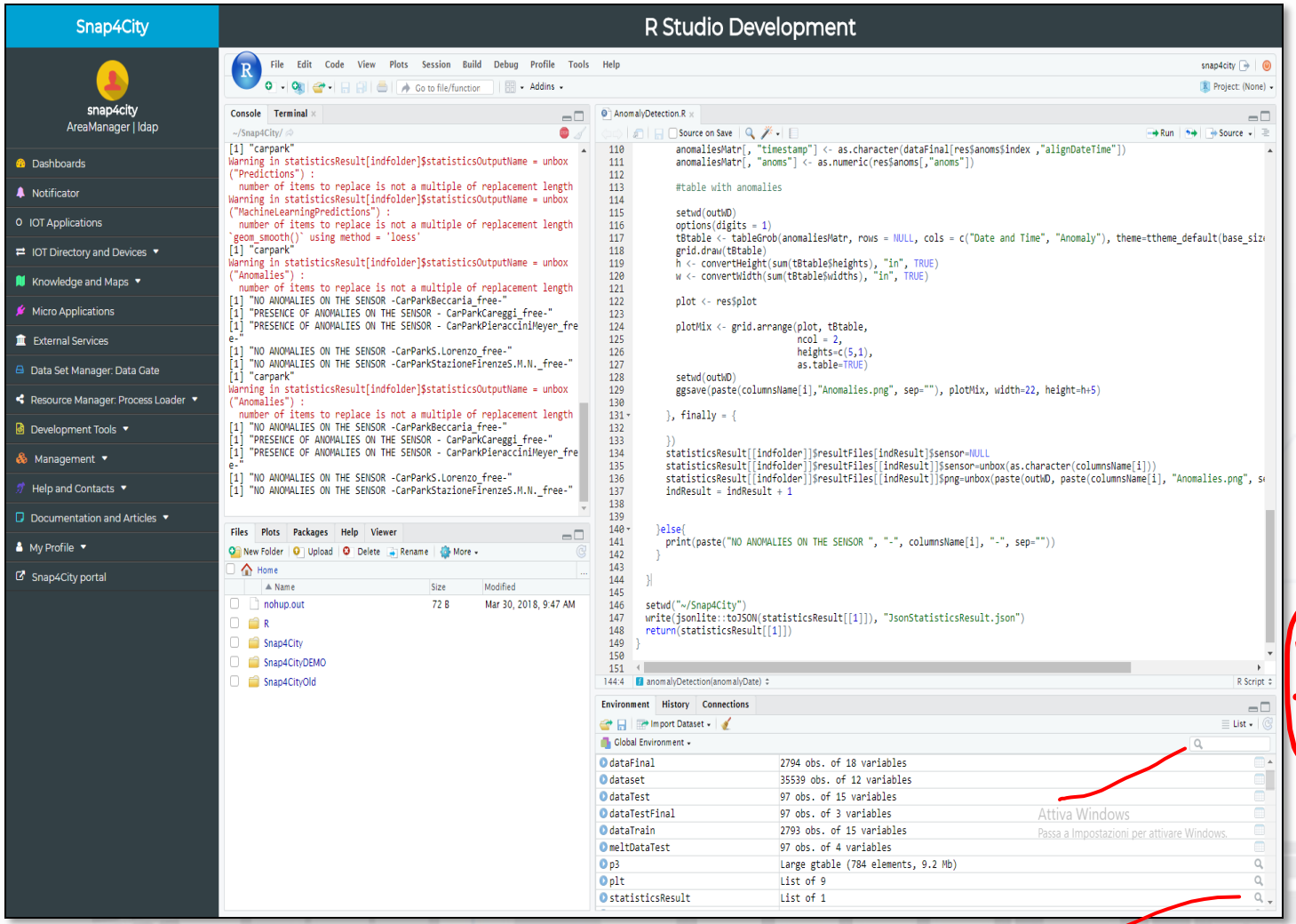
- **Mobility and Transport**
- **Environment, Weather, Waste, Water**
- **City Users Behaviour and Social analysis**
- **Energy and Control**
- **Tourism and People**
- **Security and Safety**
- **High Level Decision Support Solutions**
  - **Asset management**
  - **Resilience and Risks Analysis**
- **Low level Techniques**

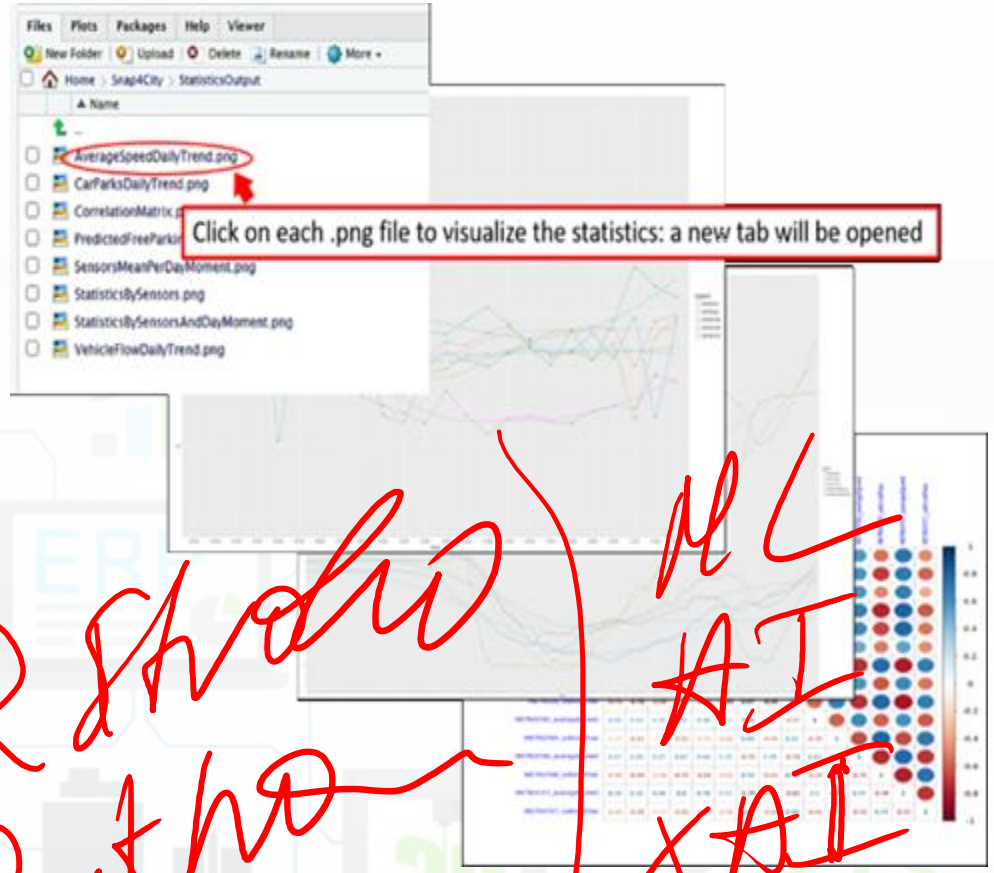


https://www.snap4city.org/download/video/DPL_SNAP4SOLU.pdf

https://www.snap4city.org/download/video/course/p4/

Developer in R Studio, Python + Tensor Flow — NVIDIA

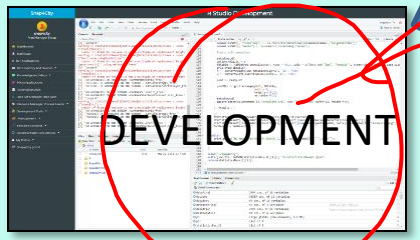




R studio
Python
Sono
ML
AI
XAI

AI/ML Infrastruct.

SNAP4CITY



python jupyter R Studio

API

Snap4City API

API

EXECUTION

Node-RED

IOT Application

API

API

API

CLEAR|ML

S4CDataAnalytic

plumber data analytic

python data analytic

docker

NVIDIA CUDA

NVIDIA CUDA

NVIDIA CUDA

CPU

HPC

API

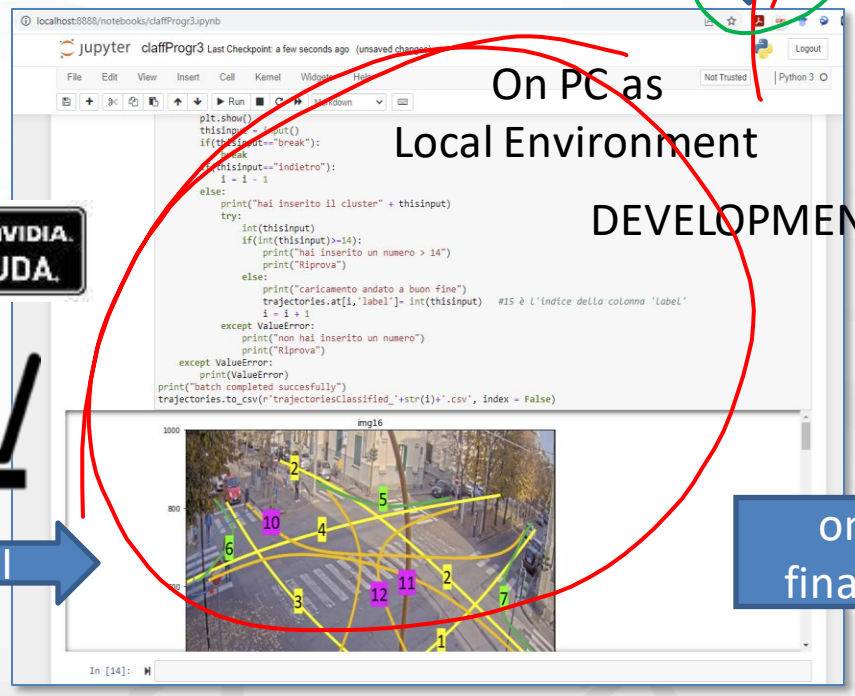
Servers

On Server or On PC

NVIDIA CUDA

On PC as Local Environment

DEVELOPMENT



Any API

once finalized

A

B

C

NVIDIA CUDA API

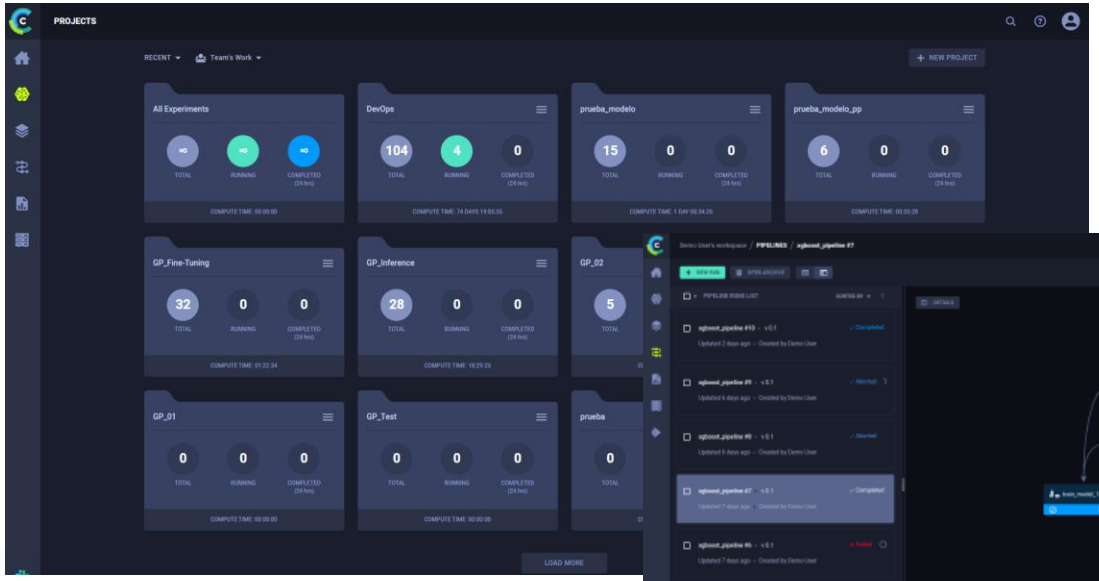
Server Execution

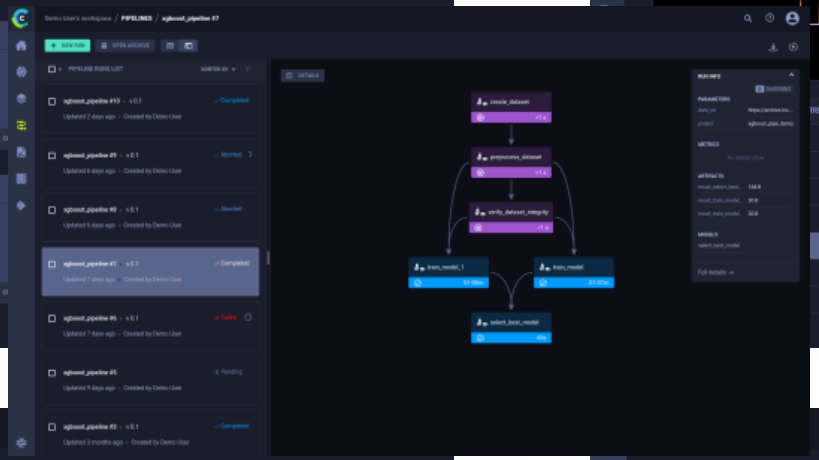
Process: file .R or .Py (+ the AI/ML model, data) can be put in execution with local scheduler or Cron

Managing AI/ML operation/development: MLOps

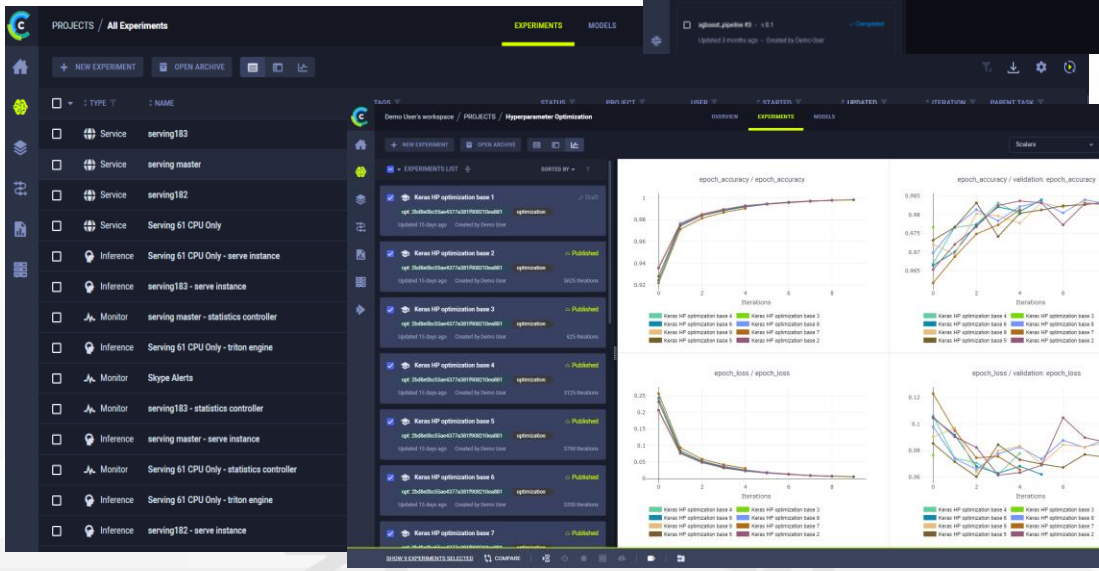
- **Management of AI/ML processes**: training and execution
- **Training needs**: several processes
  - with different parameters and models to be trained, validated and test in batch to find the best results wrt metrics
  - High computational costs, time consuming if the processes have to be sent on GPU/CPU manually
- **Execution needs**, single executions in most cases singularly cheaper, but expensive for large volume of executions:
  - periodically as predictions (saving time if the model is loaded permanent)
  - on demand as optimisation, clustering, etc. (loading model, burning time)

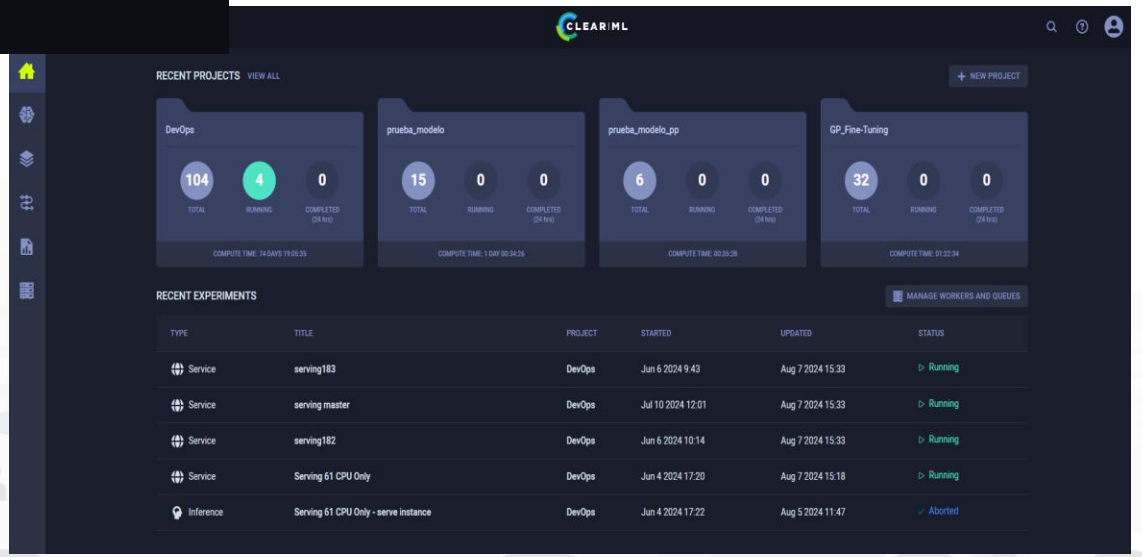
ClearML on S4C









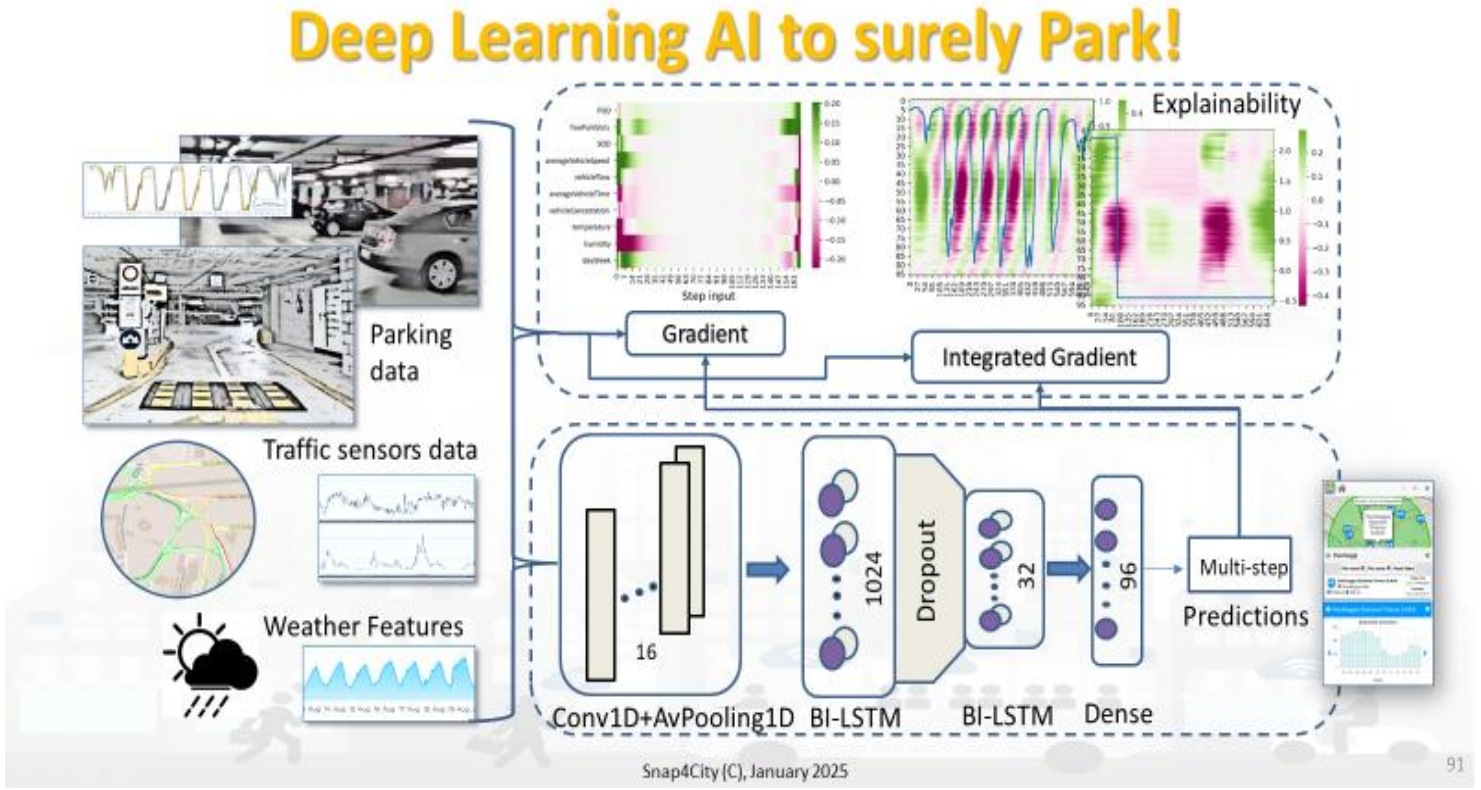


Open day

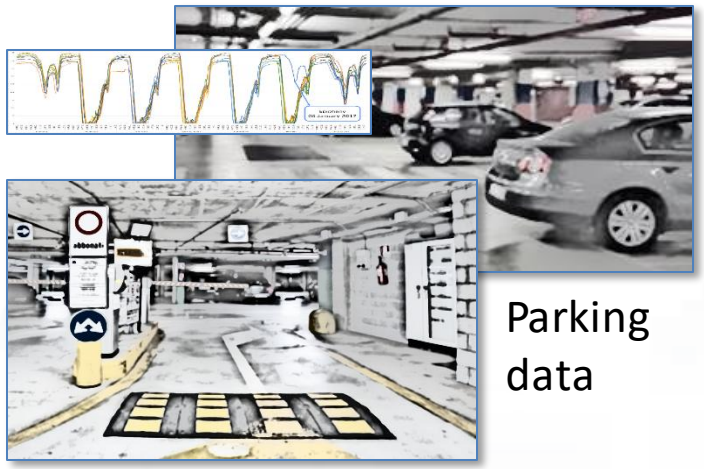
Pensa in grande, inizia da qui

Intelligenza Artificiale al servizio della città

- **Gestione Operativa, in tempo reale:**
  - **Predizioni a breve e lungo termine**
  - **Identificazione** di **anomalie** per interventi tempestivi.
  - Oggi si usano modelli di **Deep Learning:…**
    - **molti strati di reti neurali**
    - **Explainable AI: per fornire al decisore le motivazioni del suggerimento fornito dal modello di AI**



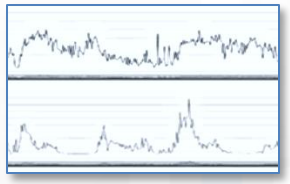
Deep Learning AI to surely Park!



Parking data

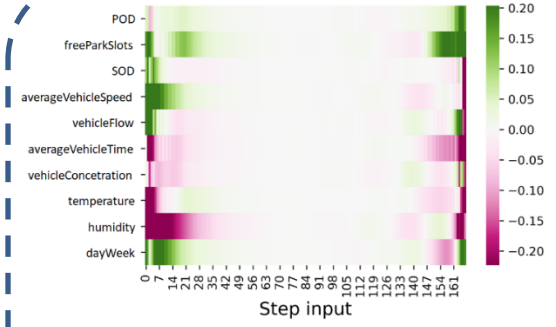
Traffic sensors data

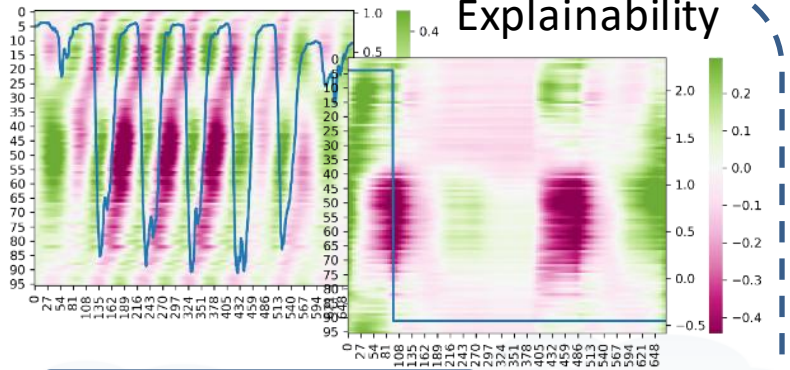




Weather Features



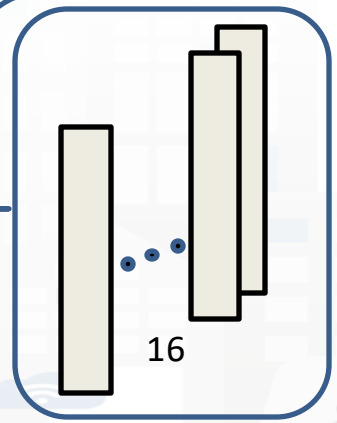


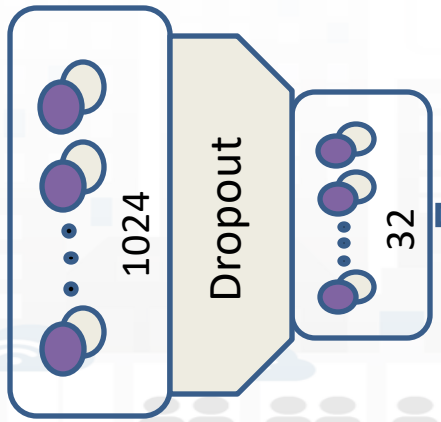


Explainability

Gradient

Integrated Gradient





Conv1D+AvPooling1D BI-LSTM BI-LSTM Dense

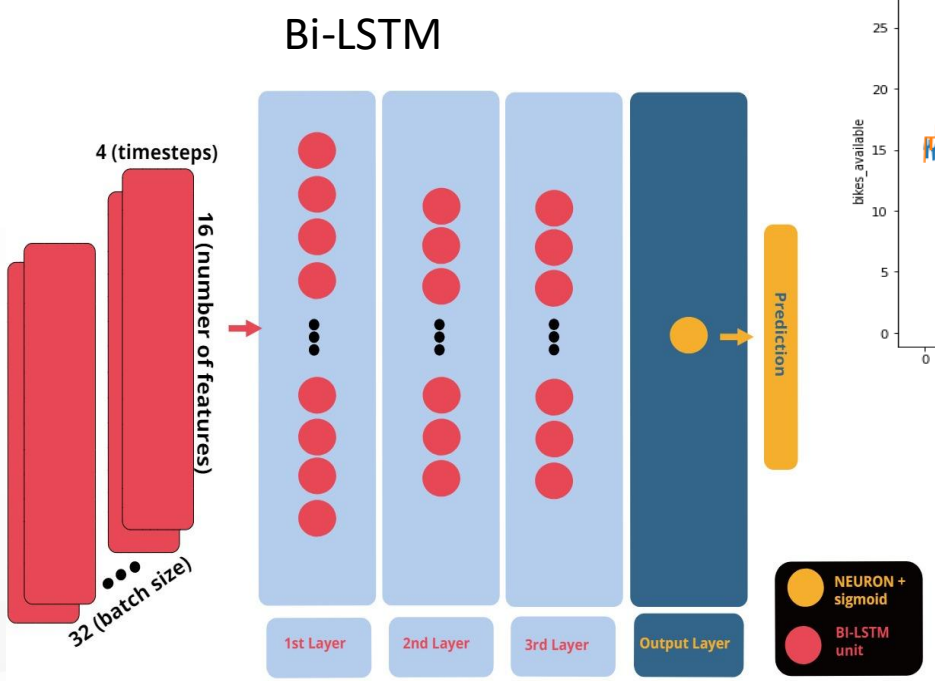
Multi-step Predictions

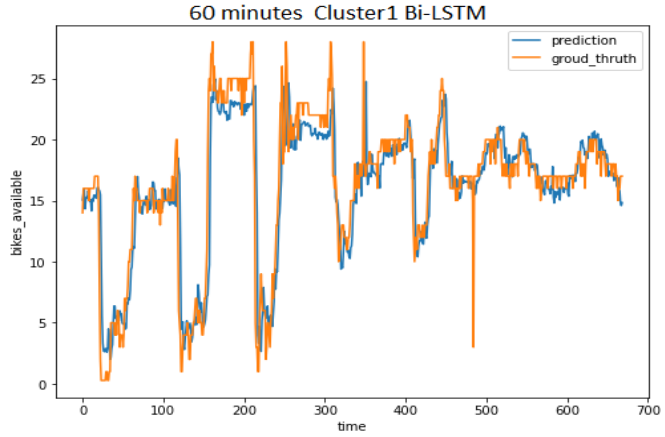


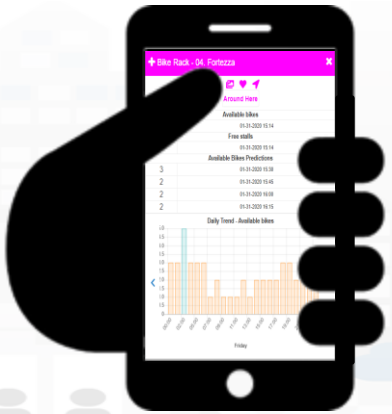
Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations





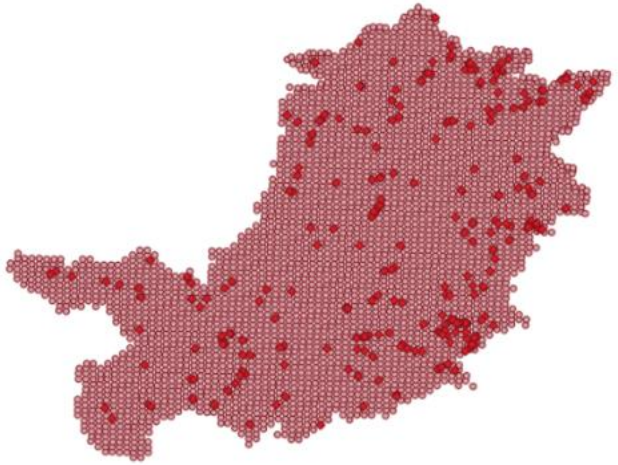


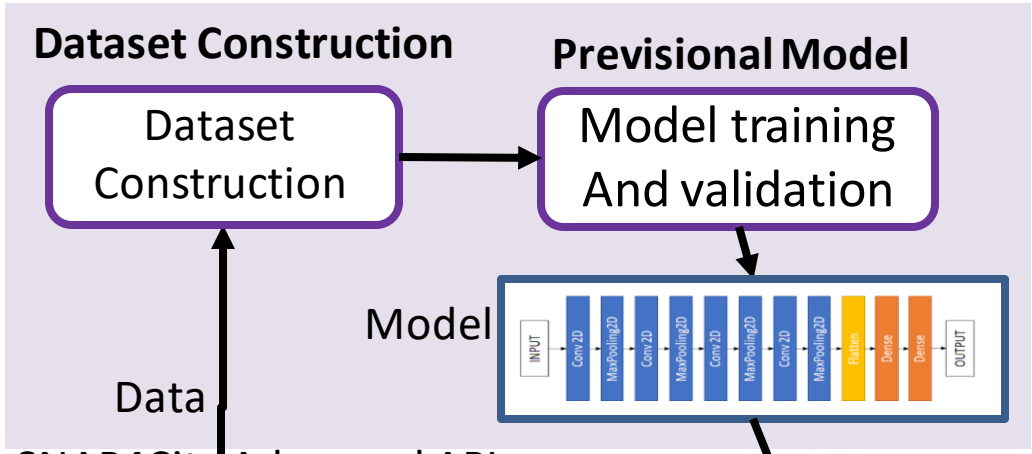


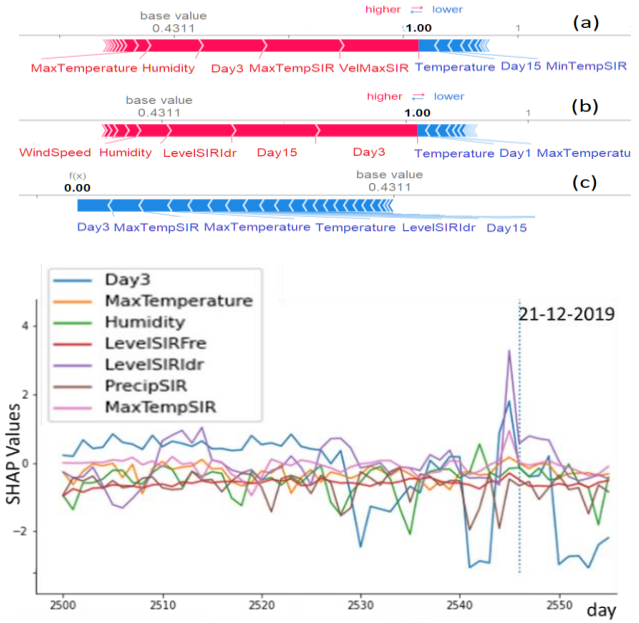


E. Collini, P. Nesi and G. Pantaleo, "Deep Learning for Short-Term Prediction of Available Bikes on Bike-Sharing Stations," in *IEEE Access*, vol. 9, pp. 124337-124347, 2021, doi: 10.1109/ACCESS.2021.3110794.
https://ieeexplore.ieee.org/abstract/document/9530580

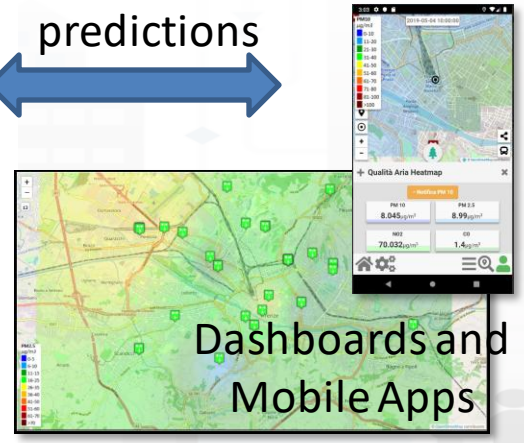
Predicting Land slides







predictions



E. Collini, L. A. I. Palesi, P. Nesi, G. Pantaleo, N. Nocentini and A. Rosi, "Predicting and Understanding Landslide Events with Explainable AI," in *IEEE Access*, doi: 10.1109/ACCESS.2022.3158328.
https://ieeexplore.ieee.org/abstract/document/9732490

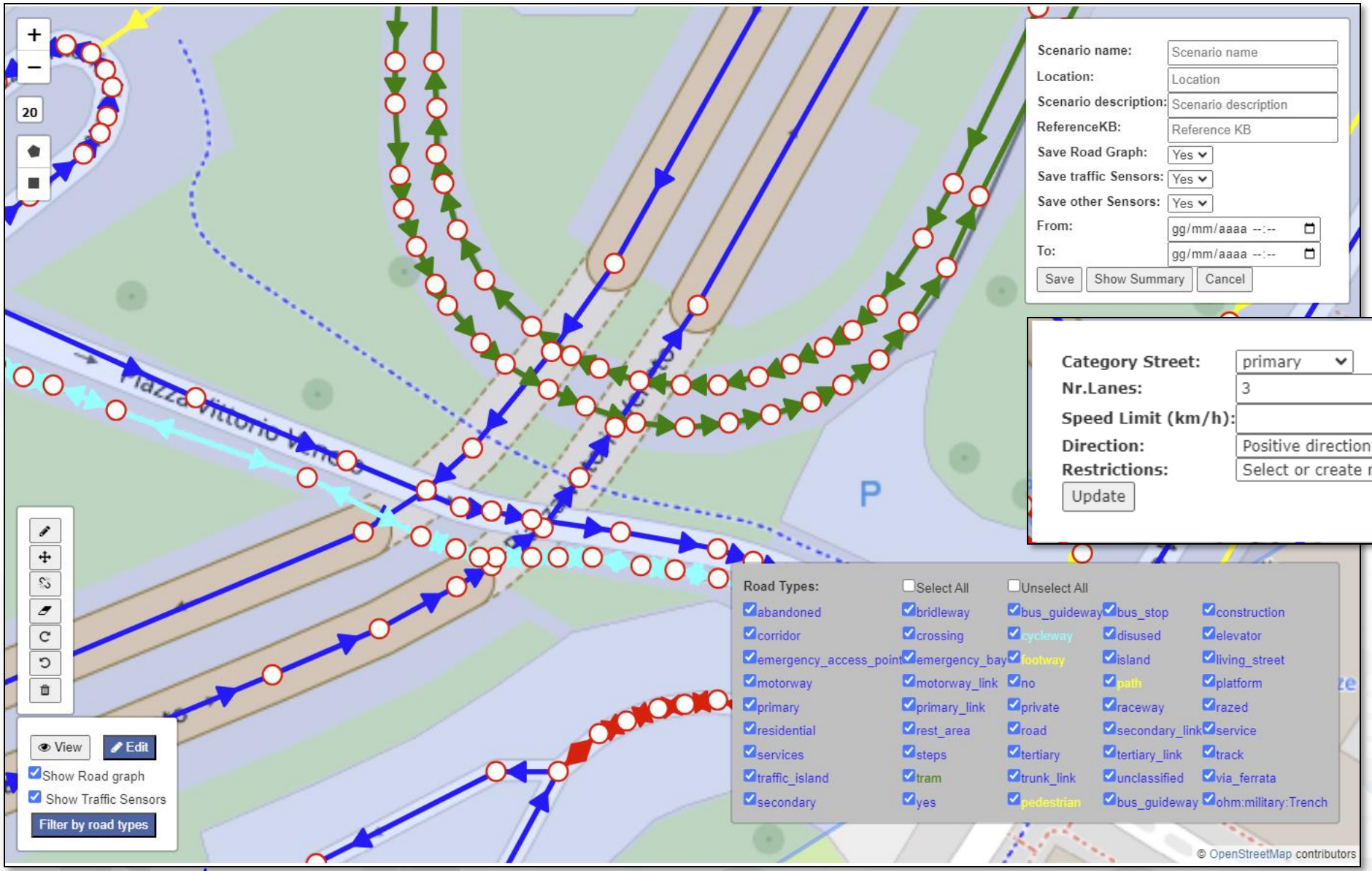
Scenario Editor

Select map

Zoom

New Scenario

Editing
Drag & drop
Split & Join
Delete
Do and Undo



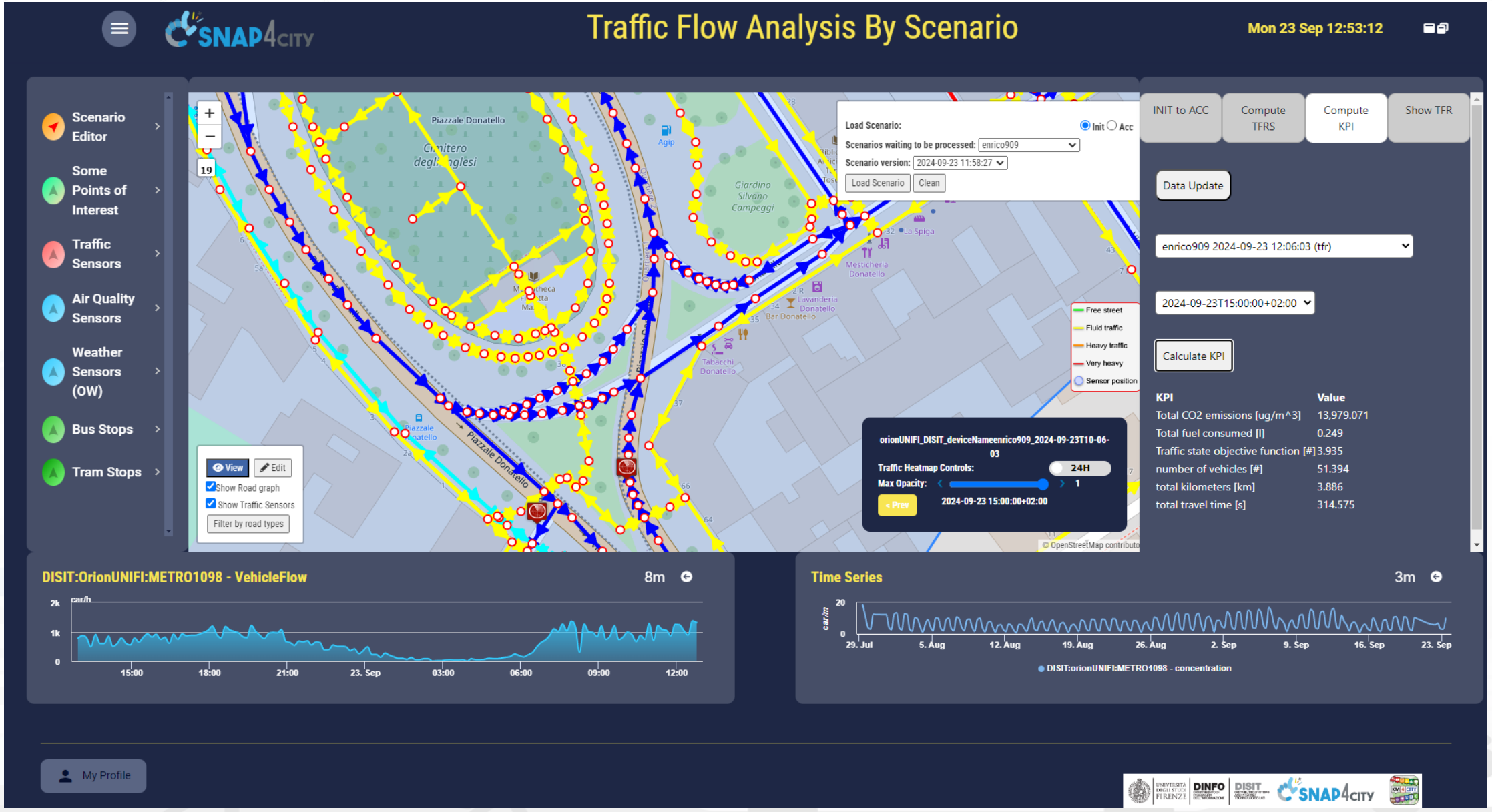
Edit Road Segment

- identifier
- composition
- elemLocation
- elementClass
- elementType
- length
- operatingStatus
- speedLimit
- trafficDir
- width
- highwayType
- route

Properties of Road Elements

https://www.snap4city.org/976

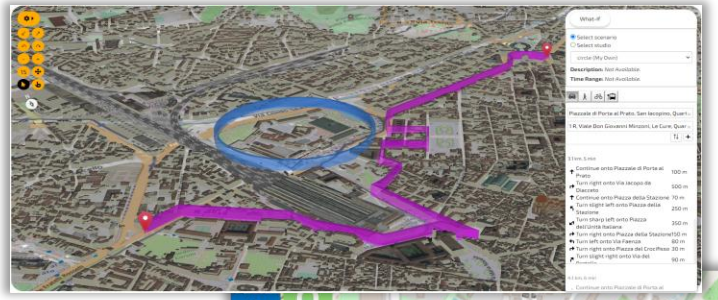
What-if on TFR

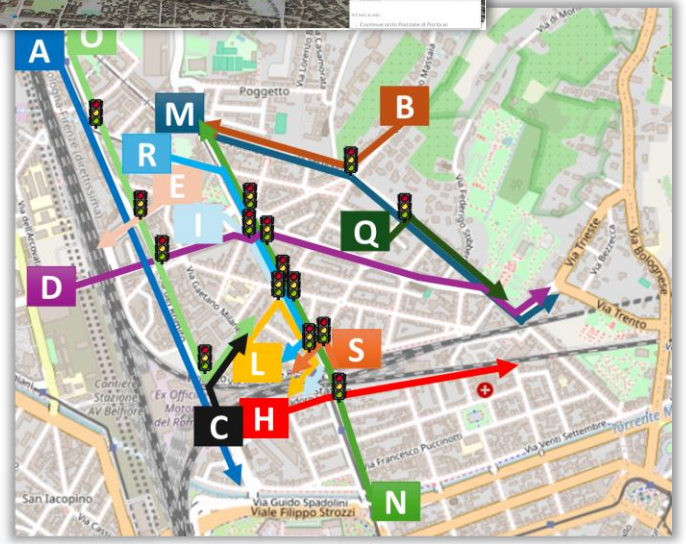


Micro Simulation



Mobility

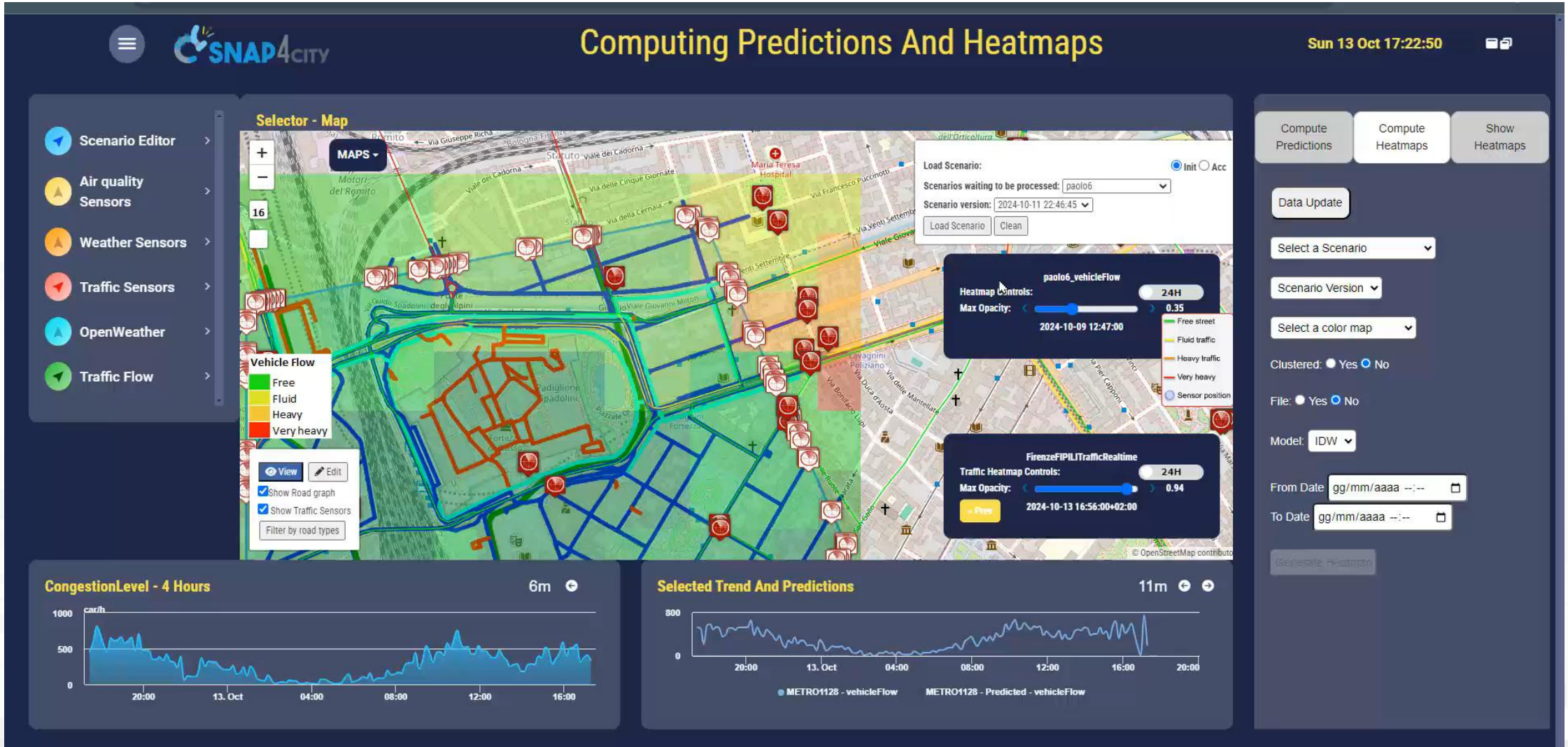






- **Goals:**
  - Decongestion, Decarbonization, costs reductions
  - Improve Accessibility to services
  - Improve Security/Safety of city users
- **Operation and Plan**:
  - Traffic monitoring, prediction, reconstruction, identification of critical conditions (early warning), fleet management, dynamic routing, multimodal routing, city user behaviour analysis
- **Optimization and what-if analysis traffic light, infrastructure**
  - **Reduction**: travel time, waiting time, stops, CO2 emissions, consume fuel, travel time for tramways
- **Public Transport**: analysis of Mobility Demand vs Offer of Transportation
- **Parking Management:** monitoring, prediction, any payments, on/off-road
- **Sharing / Pooling Management**: eShare and mobile app, bikesharing, smart bike, fleet management
- **KPI:** SUMI/SUMP, travel time, emissions, traffic status, accessibility, ..
- **Mobile App**: final users and operators
  - Info Mobility, traffic reconstruction, charging, participation,
  - Parking, payments, overparking, fine reporting, ..
- **Participatory**: problem reporting, ticketing, etc.
- **Data Integration of any kind: env, weather. Tickets, presences, POI, sat, etc.**

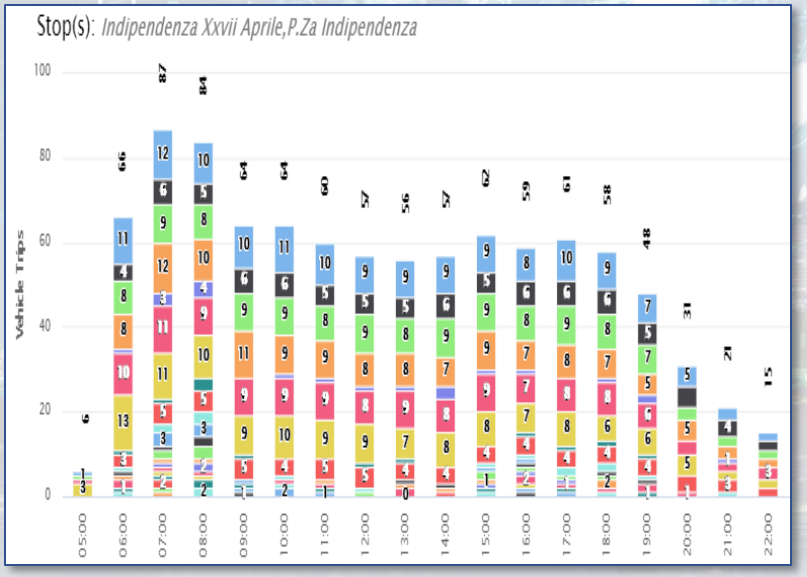
Predictions and Heatmaps in Real Time

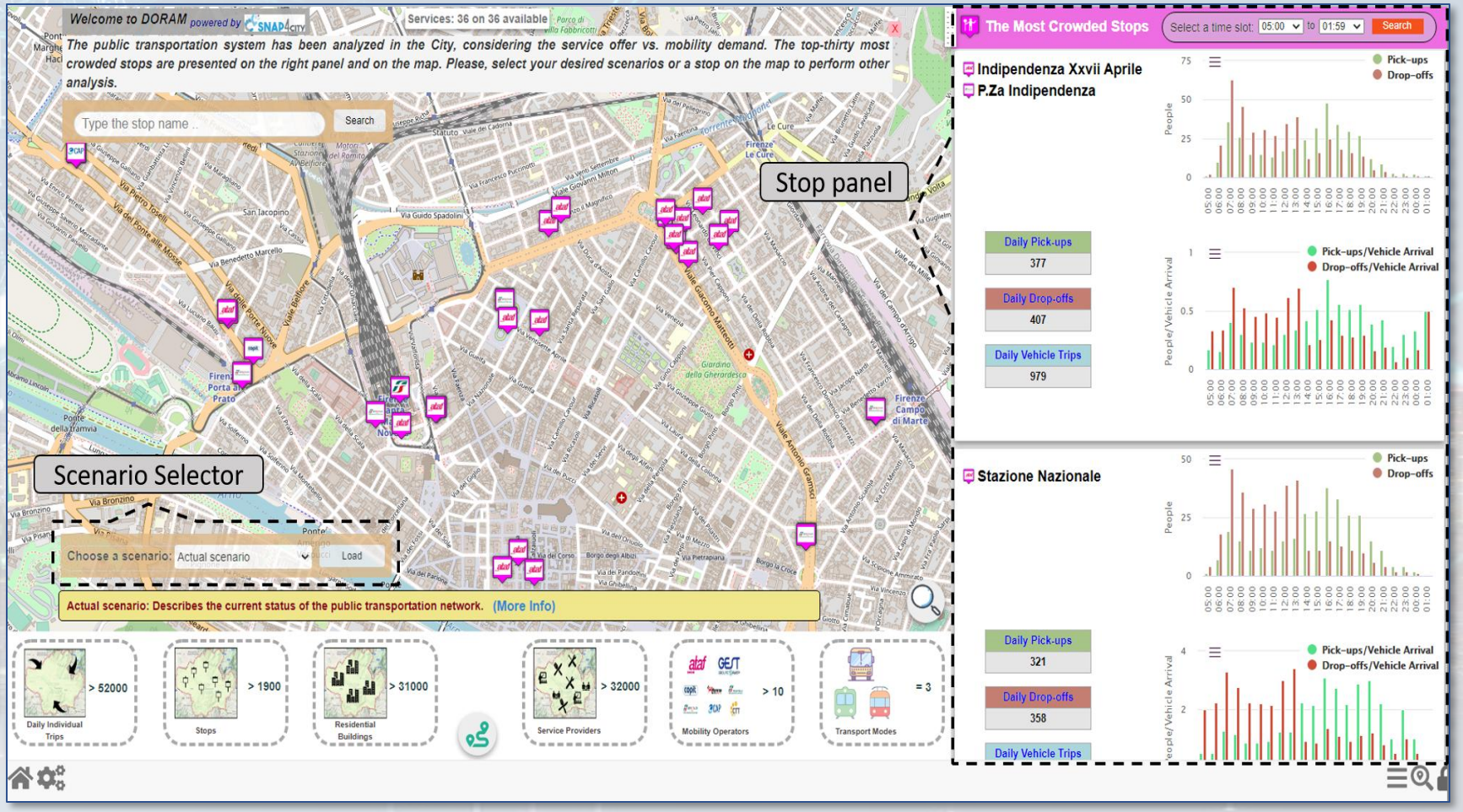


What-if Analysis on Pub Transport

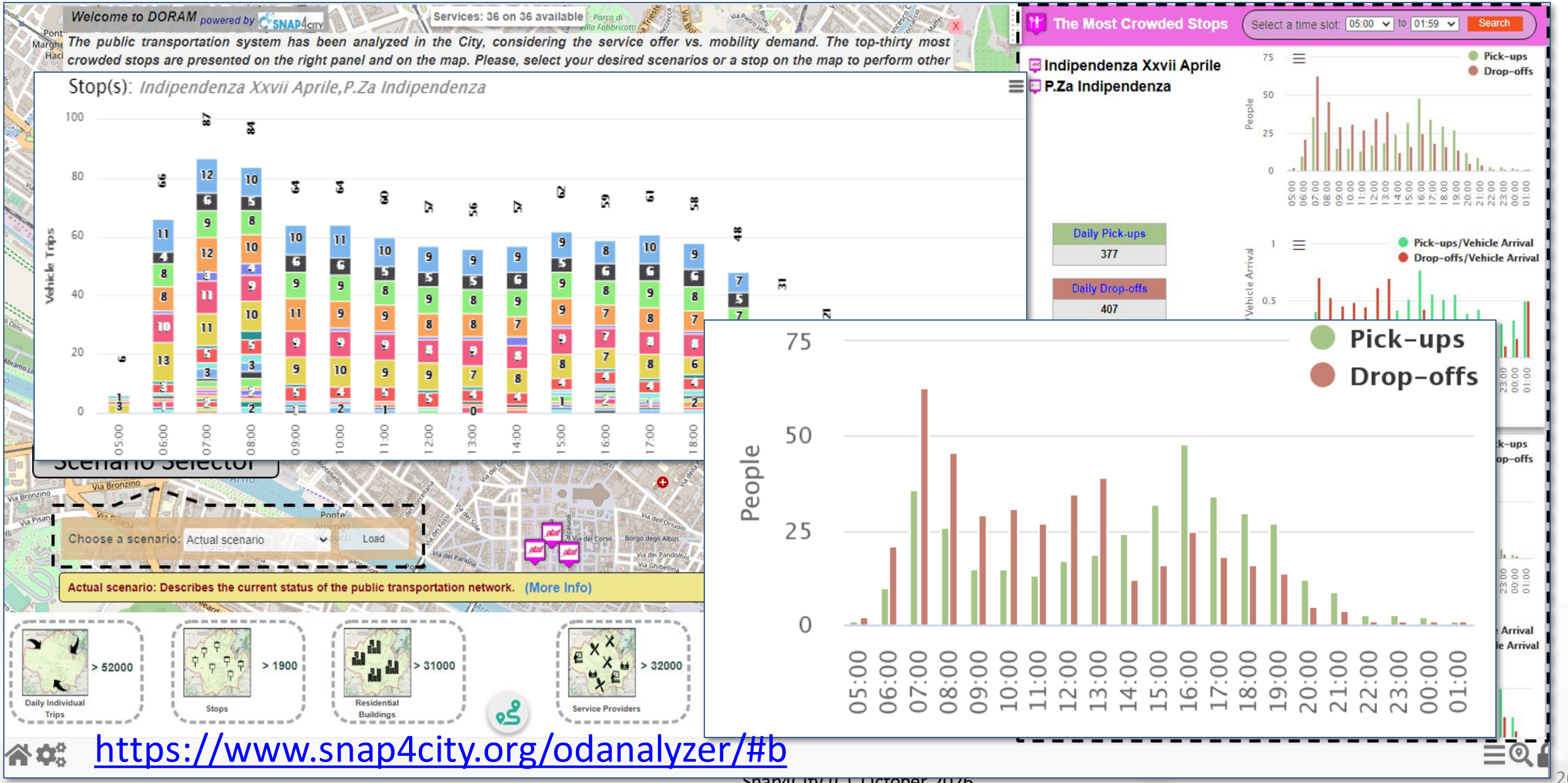
- Simulation / analysis of Demand and Offer of transportation
- Definition of scenarious impact on
  - Traffic, Pollutant, parking, public transport, private flows, etc.
  - KPI analysis

Public Services





DORAM



https://www.snap4city.org/odanalyzer/#b

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SNAP4CITY | KM4CITY

Traffic Light Plan Optimization



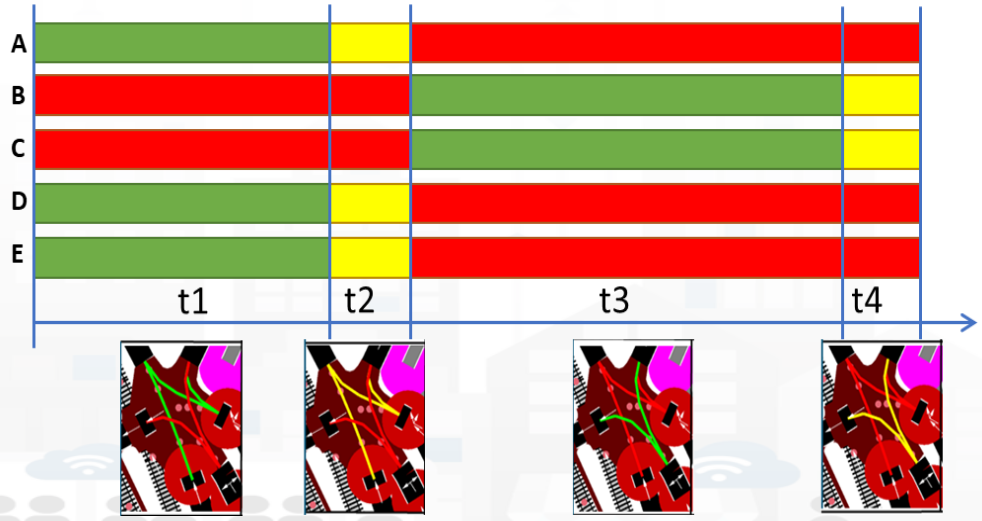
MOST
CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

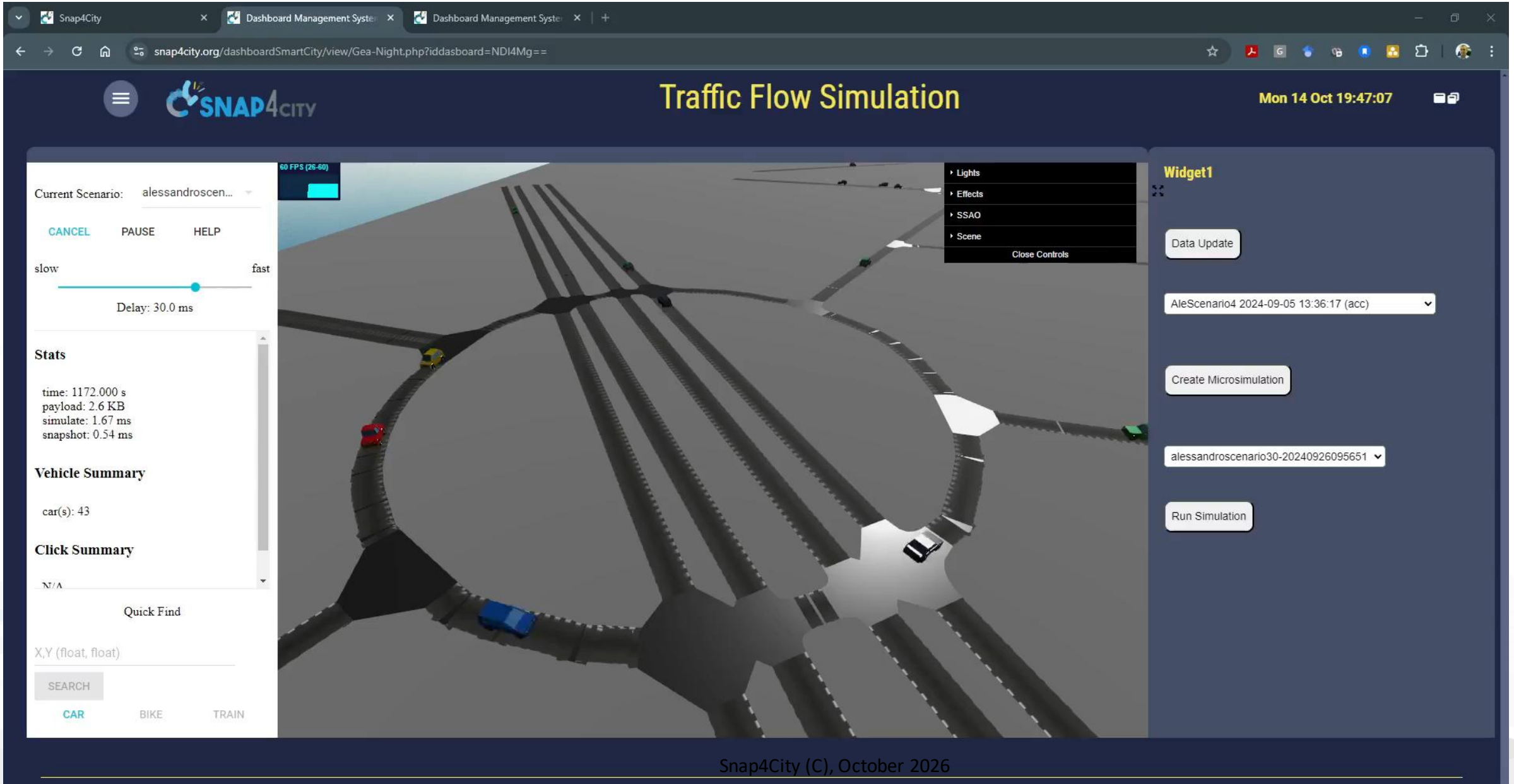
11 SUSTAINABLE CITIES AND COMMUNITIES

https://www.snap4city.org/1015

Traffic Light Plan Optimisation, Digital Twin

- **Match Multiple Objectives and Synchronization:**
  - public and private traffic, tramway priority
  - Micro and Macro Scales
  - **AI: Genetic Algorithms, Reinforced Learning**
    - Fixed and Actuated Cycles
    - Adjusted on Demand
- **Validation/integ.** with ***SUMO*** simulation
  - Travel Time, waiting time, waiting count, specific travel time on directions, CO2 emissions, etc.
- **Reductions from 5% to 15%**




Snap4City
Dashboard Management Syste
Dashboard Management Syste
snap4city.org/dashboardSmartCity/view/Gea-Night.php?iddasboard=NDI4Mg==
SNAP4CITY
Traffic Flow Simulation
Mon 14 Oct 19:47:07
Current Scenario:
alessandroscen...
CANCEL
PAUSE
HELP
slow
fast
Delay: 30.0 ms
Stats
time: 1172.000 s
payload: 2.6 KB
simulate: 1.67 ms
snapshot: 0.54 ms
Vehicle Summary
car(s): 43
Click Summary
N/A
Quick Find
X,Y (float, float)
SEARCH
CAR
BIKE
TRAIN
60 FPS (26-60)
Lights
Effects
SSAO
Scene
Close Controls
Widget1
Data Update
AleScenario4 2024-09-05 13:36:17 (acc)
Create Microsimulation
alessandroscenario30-20240926095651
Run Simulation

Mean Travel Time

	Traffic Load	MTTall	MTT dir_N	MTT dir_M	MTT dir_A	MTT TW Careggi	MTT TW Costanza
4TW-NTNS-MWD-P	1.5	3542.50	198.90	**242.14**	197.64	**436.00**	**427.00**
4TW-NTNS-MWD-A	1.5	**3242.71**	**178.33**	**243.28**	**195.79**	**436.00**	**427.00**
4TW-NTNS-MWD-P-A	1.5	**3242.71**	**178.33**	**243.28**	**195.79**	**436.00**	**427.00**
2TW-NTNS-MWD-P	1.5	4538.02	207.40	456.14	615.00	**436.00**	**427.00**
2TW-NTNS-MWD-A	1.5	3940.07	**179.30**	428.67	481.53	**436.00**	429.75
2TW-NTNS-MWD-P-A	1.5	4380.63	182.05	456.59	654.21	**436.00**	**427.00**
SUMO Actuated	1.5	3409.13	280.09	515.34	200.66	497.54	499.81
Webster	1.5	6474.95	465.45	441.93	210.50	1379.25	493.87
WebsterAdjusted	1.5	4035.08	195.82	441.09	205.66	463.87	447.06

4TWD-NTNS-MWD-P-A: optimization by prioritizing traffic **directions,** the normalized number of vehicles stops, $NTNS$, the mean waiting delay MWD, for all traffic lights, and post synchronization, with Penalty and Adjust dynamically performed

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Traffic Infrastructure Optimization



MOST
CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

FROM CITY DASHBOARD TO APPLICATIONS

MEDIA ANALYSIS

TO ADOPT 4CITY, AND ROADMAP

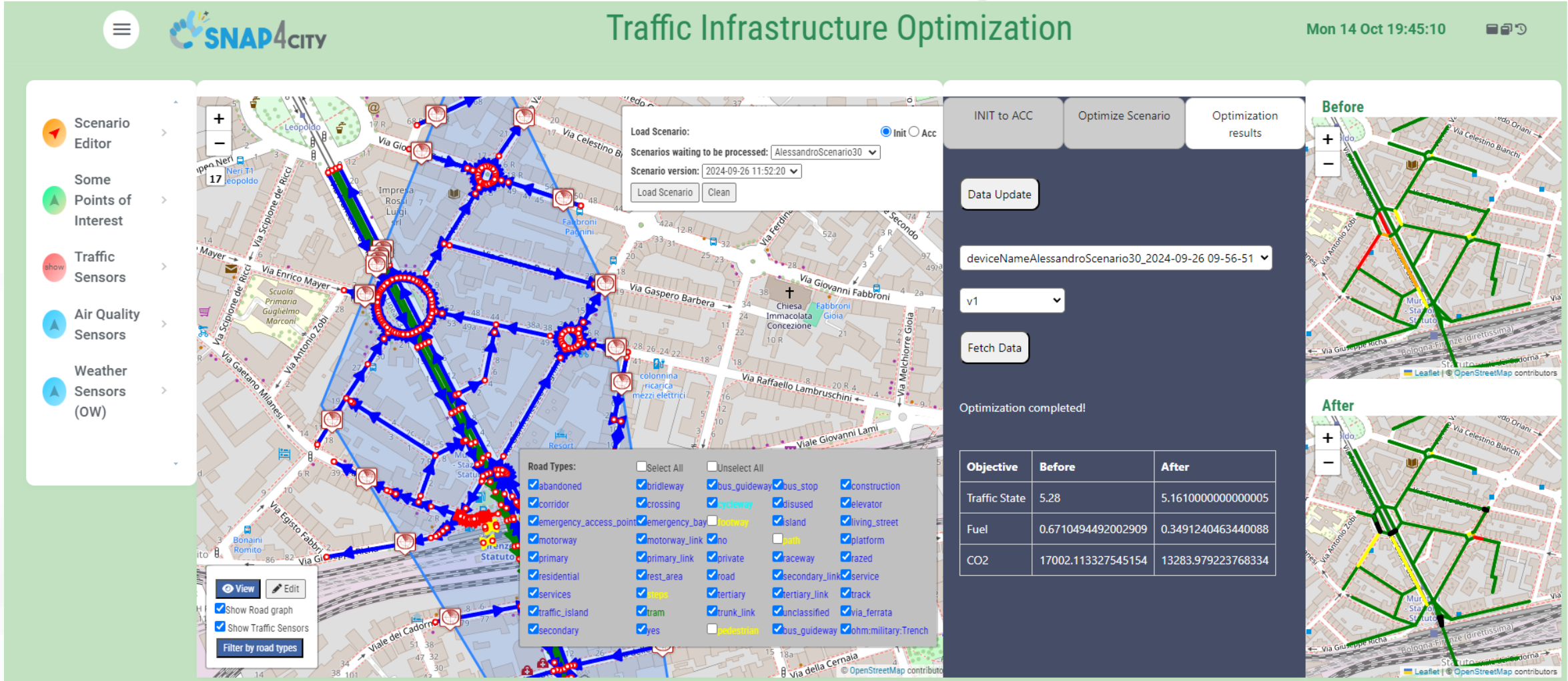
SNAP4CITY THE VIEW OF THE ADMINISTRATORS

11 SUSTAINABLE CITIES AND COMMUNITIES

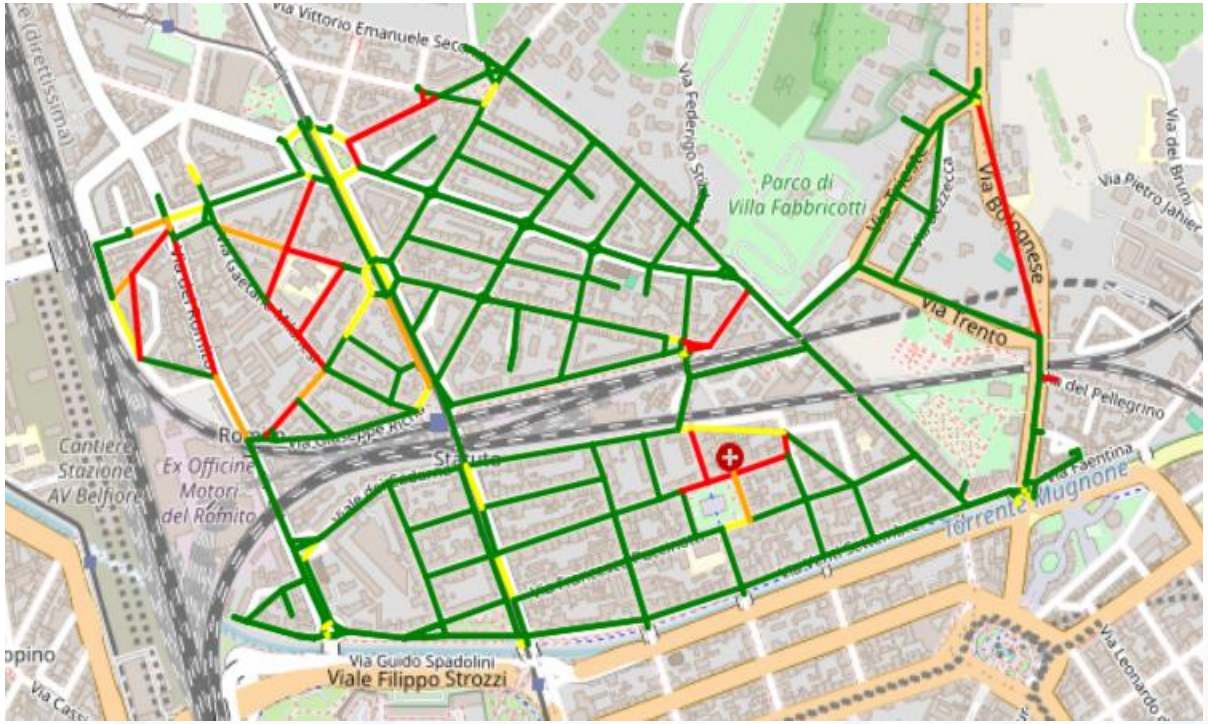
https://www.snap4city.org/1014

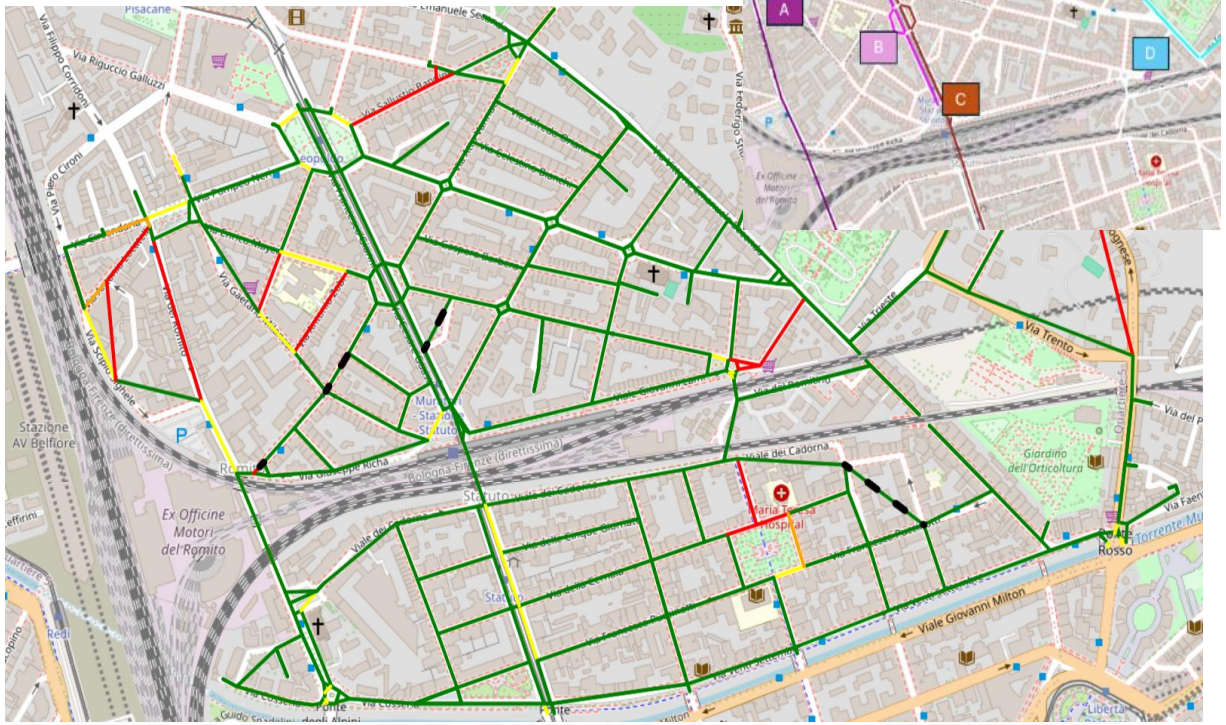


Traffic Infrastructure Optimization



Optimization Results





Case max 4 changes	*KPI estimation on the best solution*		
Optimization Target	***Traffic State***	***Fuel***	***CO2***
Optim 4 Traffic State	**91.341** -21%	17.964	128536
Optim 5 Fuel	91.514	**16.633** -35%	128227
Optim 6 CO2	92.859	19.192	**127876** -23%
Original	115.475	25.680	165822

Travel Time [s]	*Path A*	*Path B*	*Path C*	*Path D*	*Total Time*
Original Scenario	183.2	59.6	80.9	132.5	456.4
Optim 4 Traffic State	93.2	60.0	63.7	**96.0**	313.1
Optim 5 Fuel	89.6	**51.2**	59.7	96.4	**296.9**
Optim 6 CO2	**89.5**	53.2	**58.4**	100.1	301.3
	-51%	-14%	-28%	-28%	

Environment and Waste

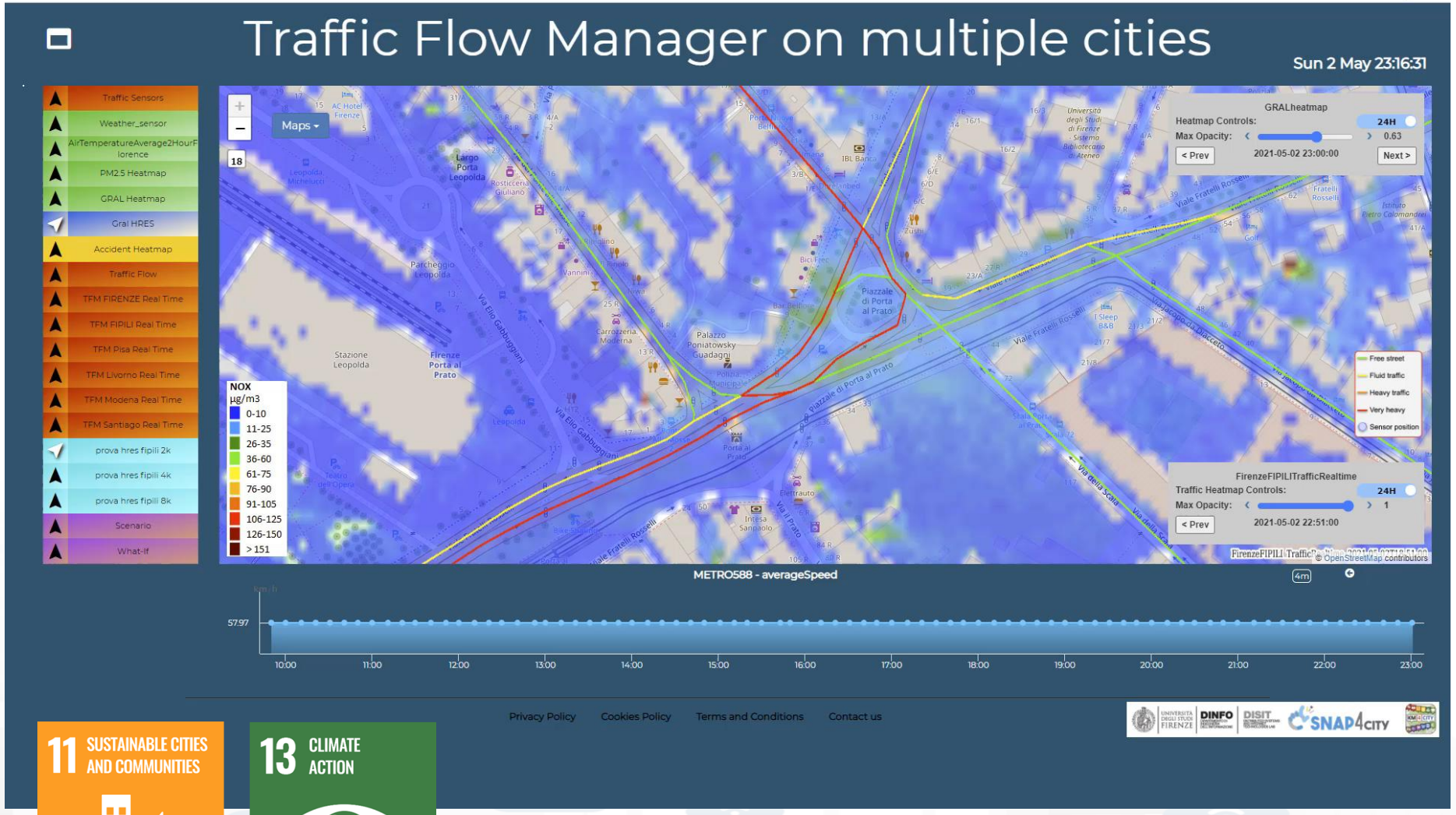
- **Goals:**
  - Reduction of emissions and EC taxations
  - Cost reduction for waste collection,
  - reduction of waste collection impact on mobility
- **Environment Management producing prescriptions:**
  - Monitoring and long and short-term predictions, warning for:
    - GHG, emissions, pollutants, aerosol, chemical plants analysis
    - land slide, coastal erosion (blue economy)
  - Traffic Flow impact emissions, predictions
  - What-if analysis, optimisation tools
- **Waste Management and Optimisation:**
  - costs reduction, optimal routing production, pay as you throw,
  - avoiding out of bins, predictions of waste production on bins, alarms
- **KPI:** SDG, 15MinCityIndex, QOS, costs, Km, colleting time, EC KPI, emissions
- **Mobile App**: final users services/informing and operators
  - Info Waste for operators, participation, optimal routing, RAEE Collection, ..
- **Participatory**: problem reporting, ticketing, etc.
- **Integration of any kind: env/weather, mobility, ticketing, presences, POI, ..**





Environment

- **Prediction**
  - **NOX Pollutant** diffusion on the basis of Traffic Flow (prediction), weather and 3D structure
  - **NO2 progressive average** (Long term)
- **Project:**
  - **Trafair** CEF EC
  - Mixed solutions of Fluidinamics modeling and AI

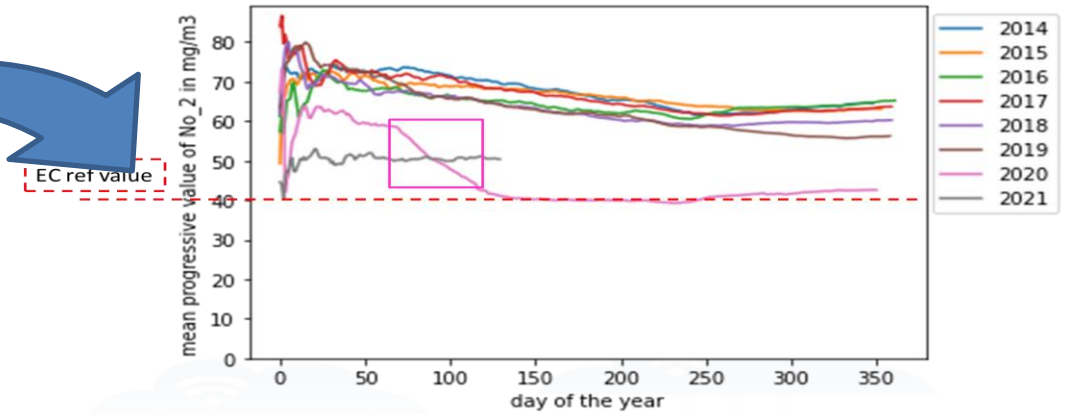




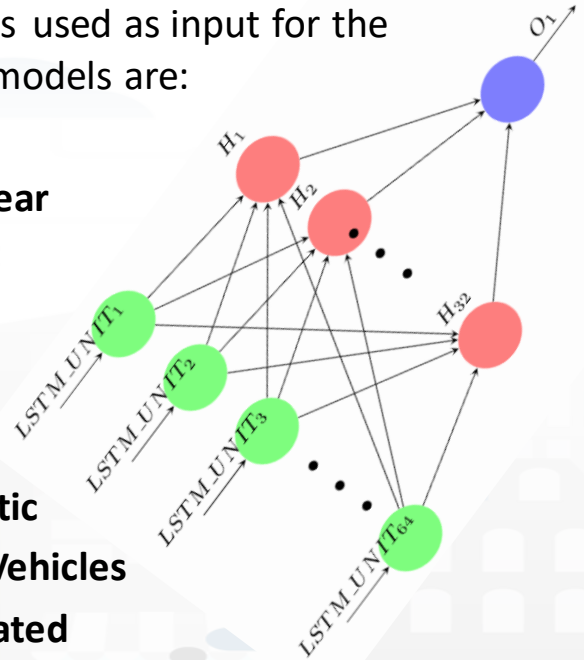


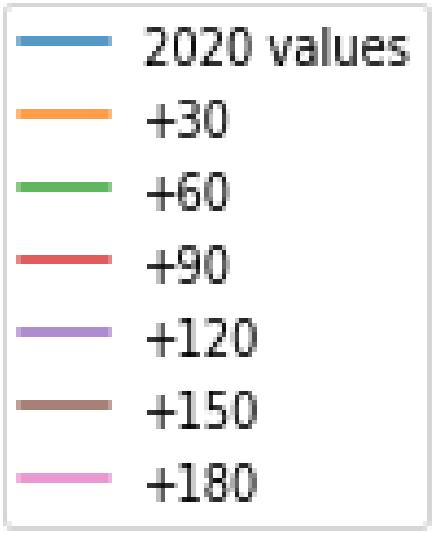
Predicting EC's KPI on NO2 months in advance

Deep Learning Long Terms Predictions of NO2 mean values, From 30 to 180 days in advance



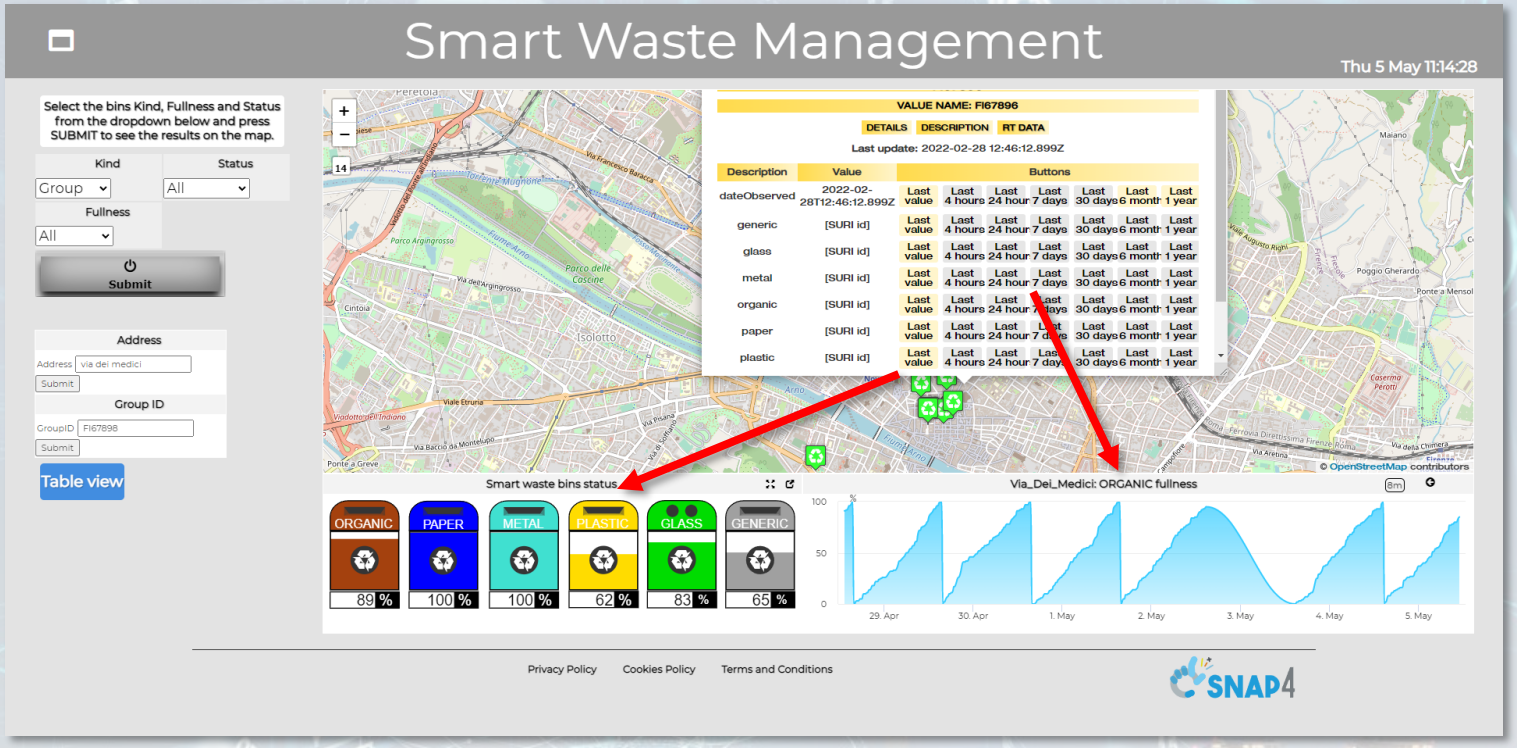
- The features used as input for the predictive models are:
- **Month**
- **dayOfTheYear**
- **NO2**
- **Tmean**
- **Humidity**
- **windMean**
- **NoxDomestic**
- **numberOfVehicles**
- **NO2cumulated**
- **NO2progresseveMean**
- **numberOfVehiclesCumulated**





	Air Quality Directive			WHO guidelines	
Pollutant	Averaging period	Objective and legal nature and concentration	Comments	Concentration	Comments
$PM_{2.5}$	One day			25 µg/m³ (*)	99th percentile (3 days/year)
$PM_{2.5}$	Calendar year	Target value, 25 µg/m³	The target value has become a limit value since 1 January 2015	10 µg/m³	
PM_{10}	One day	Limit value, 50 µg/m³	Not to be exceeded on more than 35 days per year.	50 µg/m³ (*)	99th percentile (3 days/year)
PM_{10}	Calendar year	Limit value, 40 µg/m³ (*)		20 µg/m³	
O_3	Maximum daily 8-hour mean	Target value, 120 µg/m³	Not to be exceeded on more than 25 days per year, averaged over three years	100 µg/m³	
NO_2	One hour	Limit value, 200 µg/m³ (*)	Not to be exceeded more than 18 times a calendar year	200 µg/m³ (*)	
NO_2	Calendar year	Limit value, 40 µg/m³		40 µg/m³	

Smart Waste – Map view



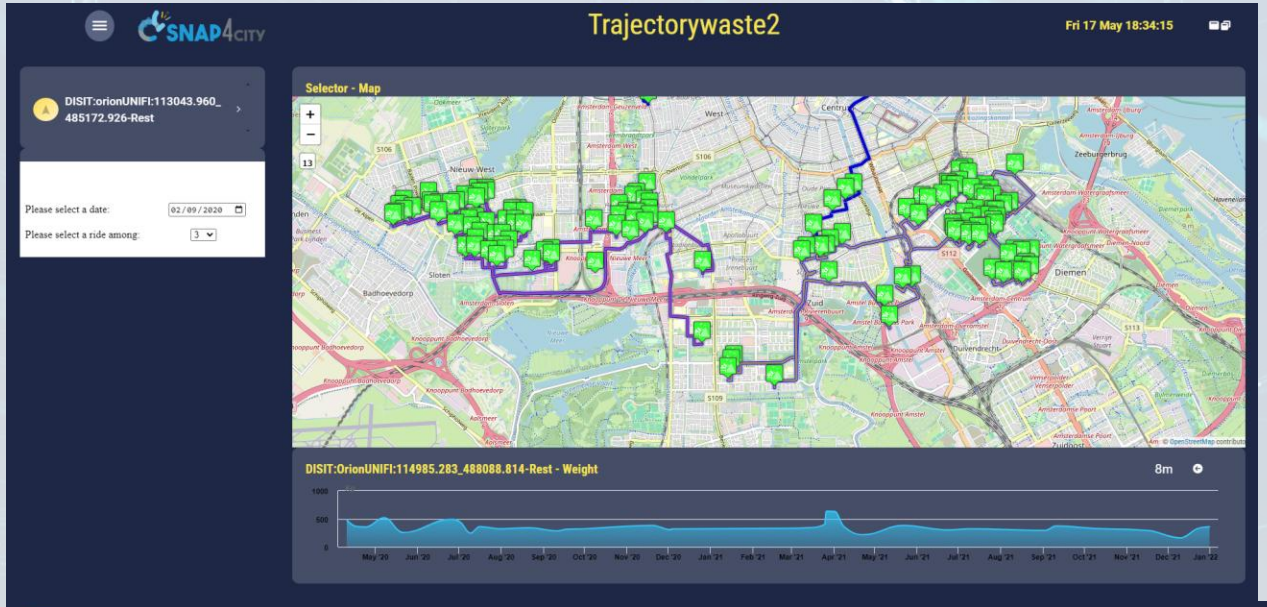
Search bins on map by filtering per:

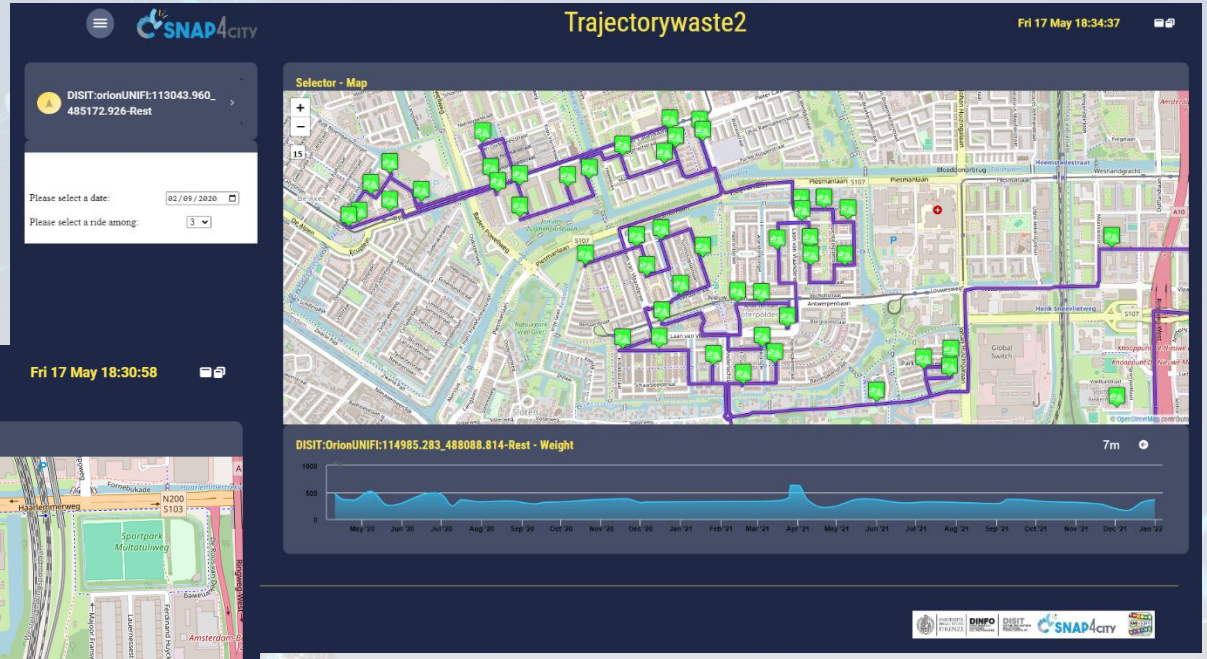
- **Kind** (All, generic, plastic, paper, glass, metal, organic)
- **Status** (Active, Not Active)
- **Fullness** (Full, Half-full, Empty)
- **Address**
- **Group of bins** (by GroupID)

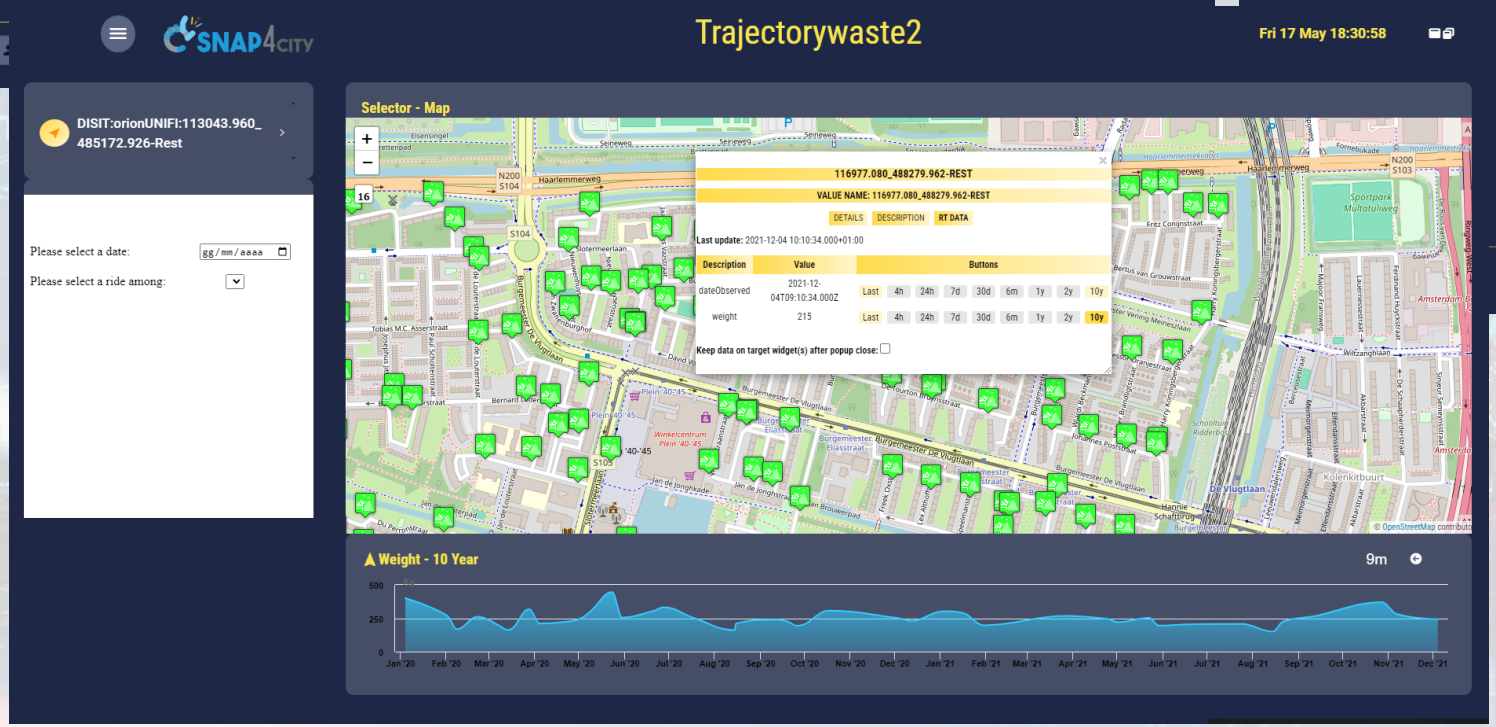
- Reduction of costs for waste collection
  - Optimization of waste collection for the next day, forecast
  - Production of rides and paths for the drivers on waste collection
- Operator:
  - Refine a search by using the filters on the left side
  - Click on a waste bin pin on the map:
  - A popup with real time data is shown
  - The fullness status of the selected group of bins is shown in the synoptic below the map
  - Specific fullness weekly trends are shown below the map
  - Chick on the «Table view» button to access the other dashboard






SNAP4CITY
Trajectorywaste2
Fri 17 May 18:34:15
DISIT:orionUNIFI:113043.960_485172.926-Rest
Please select a date:
02/09/2020
Please select a ride among:
3
Selector - Map
DISIT:OrionUNIFI:114985.283_488088.814-Rest - Weight
8m


SNAP4CITY
Trajectorywaste2
Fri 17 May 18:34:37
DISIT:orionUNIFI:113043.960_485172.926-Rest
Please select a date:
02/09/2020
Please select a ride among:
3
Selector - Map
DISIT:OrionUNIFI:114985.283_488088.814-Rest - Weight
7m


SNAP4CITY
Trajectorywaste2
Fri 17 May 18:30:58
DISIT:orionUNIFI:113043.960_485172.926-Rest
Please select a date:
gg/mm/aaaa
Please select a ride among:
Selector - Map
116977.080_488279.962-REST
VALUE NAME: 116977.080_488279.962-REST
DETAILS
DESCRIPTION
RT DATA
Last update: 2021-12-04 10:10:34.000+01:00
Description
Value
Buttons
dateObserved
2021-12-04T09:10:34.000Z
weight
215
Keep data on target widget(s) after popup close:
Weight - 10 Year
9m


11
SUSTAINABLE CITIES AND COMMUNITIES

3
GOOD HEALTH AND WELL-BEING

Your AI-Powered Assistant for Smart Cities

SnapAdvisor & CoPilot

- Conversational interface
- Planning, replanning
- Agentic AI. Multi-Agent
- Analyze, Optimize
- Suggestions, reports



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SnapAdvisor is for

City operators

Monitor conditions, compare places or periods, investigate anomalies and calculate routes.



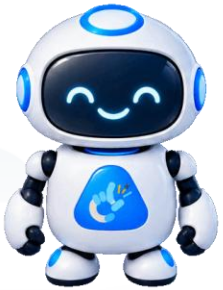
Decision makers

Collect evidence, assess scenarios and compare proposed interventions. City Officers, assessor.



Developers

Find documentation, identify APIs and use Snap4City tools to build applications.





A multilingual interface across mobility, energy, tourism and any other domains, including your private collection of document and info.

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SnapAdvisor & Copilot

Your AI-powered assistant for the Snap4City Digital Twin

Understand your objectives | Plan and use Snap4City services | Analyse data | Deliver actionable answers

Turn your questions into smarter, data-driven decisions for a smarter city.

- CLEANER CITIES
- MORE EFFICIENT OPERATIONS
- BETTER DECISIONS

Ask in natural language

- What is happening in this area?
- Find the sensors along this route.
- Which route is better considering current conditions?
- What can be done to reduce the CO_2 emissions in Mercy road at 9:00?
- Why are there no free parking slots in the Giuzzer area?
- Find an API to get data of traffic flow in Bologna?



1 Understand & Plan
Interpret your request and create a multi-step plan

2 Select & Execute
Choose and invoke the right Snap4City services and APIs

3 Analyse & Verify
Analyse results, recover from issues eventually replan

4 Deliver Answer
Provide clear, explainable results in natural language with visuals

Snap4City Services & APIs

- Access data (live & historical)
- Discover IoT devices
- GIS and geospatial tools
- Analytics and AI models
- Optimisation & what-if analysis
- Open to any data model and format

Actionable results

Here is the analysis of the area.
I used traffic, air quality and parking data.
You can see the results on the map, the trends over time and a summary of insights.









Key insights

- Congestion level reached 90% in Via Sparta due to an event.
- CO_2 emissions are higher at 9:00 in Mercy road.
- Alternative routes can reduce travel time by 18%.
- See the full report for details and the data sources used.

Download PDF Report

Rich knowledge foundation
Snap4City, mobility, energy, tourism, assets, transportation, GIS and more.

RAG with private collections
Use your PDFs, documents, presentations, images, code and web pages. Domain-customisable, multilingual.

Agentic capabilities
Multi-step planning, specialist agents, execution, verification and replanning.

Exploit more resources
Integrate web search and external resources. Generate decision graphs and reuse them.

Explainable AI
See the plan, tools used, data sources and reasoning behind the answer.

For multiple domains
Smart Cities | Mobility | Energy | Tourism | Assets | Transportation | GIS | Retail | Legal | Training | Help Desk | ... and more

For everyone
Decision Makers | City Operators | Developers | Organisations & Teams

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SNAP4CITY

Logged in as: paolo.disit

Your collections

Logout

Help

Selected collection:

MobilityAndTranspor

New Chat

solution1

https://www.snap4city.org/



SnapAdvisor

Current chat: solution1

Personal Advisor LLM

You:

which are the possible to solutions to reduce the lenght of queue at red lights

SnapAdvisor: Tokens details: tokens in prompt: 56759; tokens in answer: 653

Possible Solutions to Reduce the Length of Queue at Red Lights

Based on the provided context passages, here are some possible solutions to reduce the length of queue at red lights:

Traffic Management and Road Safety Measures

1. **Optimizing Traffic Light Timing**: Adjusting the timing of traffic lights to optimize traffic flow and reduce congestion.
2. **Implementing Intelligent Transportation Systems (ITS)**: Using ITS to dynamically adjust traffic light timing in real-time to respond to changing traffic conditions.

Run agentic mode

Write a message...

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SnapAdvisor & Copilot

Technical architecture for the Snap4City Digital Twin conversational decision support system

SNAP4CITY

SMART CITIES
DATA-DRIVEN
PEOPLE-CENTRIC

From natural-language objective to orchestrated analysis, simulation, and explainable decision support.

Conversational / RAG | Agentic orchestration | Multi-domain | Explainable AI | Report generation

Example Requests

- "What is happening in this area?"
- "Find sensors and POIs along this route."
- "Which route is better considering current conditions?"
- "Why are there no free parking slots in this area?"
- "What can be done to reduce CO2 emissions at 9:00?"
- "Find an API to get traffic flow in Bologna."

System Architecture & Workflow

1. **User Objective** — Natural-language request
2. **Planner / Replanner** — Interpret objective, decompose tasks, create multi-step plan
3. **Specialist Agents** — Domain-specific reasoning and task execution
4. **Snap4City Services & APIs** — Data retrieval, GIS, routing, analytics, simulations, optimization
5. **Verifier / Review** — Validate outputs, recover from failures, possibly replan
6. **Actionable Answer** — Text, maps, charts, tables, reports

Feedback (refine, replan, recover from failures)

Extend capabilities with internal skills

Turn private knowledge and web resources into reusable domain expertise

Private documents — PDFs, manuals, procedures, slides and internal reports

Web access — Search, web pages, documentation and external APIs

Internal skill library — Organisation-specific instructions, knowledge and tools

Planner & specialist agents — Select and combine skills to solve new tasks

- **Internal procedures** — Use organisational guidelines and manuals
- **Domain analysis** — Apply domain-specific methods and models
- **Custom reporting** — Generate tailored reports and templates
- **Add new skills** — Create and integrate new skills for your needs

Extend to new domains and workflows as your knowledge grows.

Tool Families

- **Data Management** — Metadata; Live/historical observations; Entities; IoT devices
- **Geospatial Analysis** — Geocoding; Spatial search; Polygons, POIs; Location-aware analysis
- **Mobility & Transport** — Routing; Traffic flow; Public transport; Simulation, KPI computation; Optimization
- **ML / AI Analytics** — Prediction; Statistics, correlation; Regression, PCA; Time-series analysis
- **Media Processing** — Image interpretation; Image generation; Image modification
- **Reporting & Rendering** — Web pages; PDF reports; Maps, charts, tables; Dashboards
- **High-Level Reasoning** — Decision graphs; Strategy generation; What-if analysis

Outputs

Explainable results with evidence, data sources, and visual analytics.

Map | Time-series chart | Bar chart | Report (PDF) | Decision graph | Summary answer

Table

Area	Value	Trend
Centro	125	▲
Stazione	98	▼
Fiera	67	▲
Borgo	43	—

Who it supports

- **Decision Makers** — Strategic planning and policy making
- **City Operators** — Monitor, manage and respond
- **Developers** — Build solutions and integrate APIs
- **Organisations / Teams** — Collaborate across domains

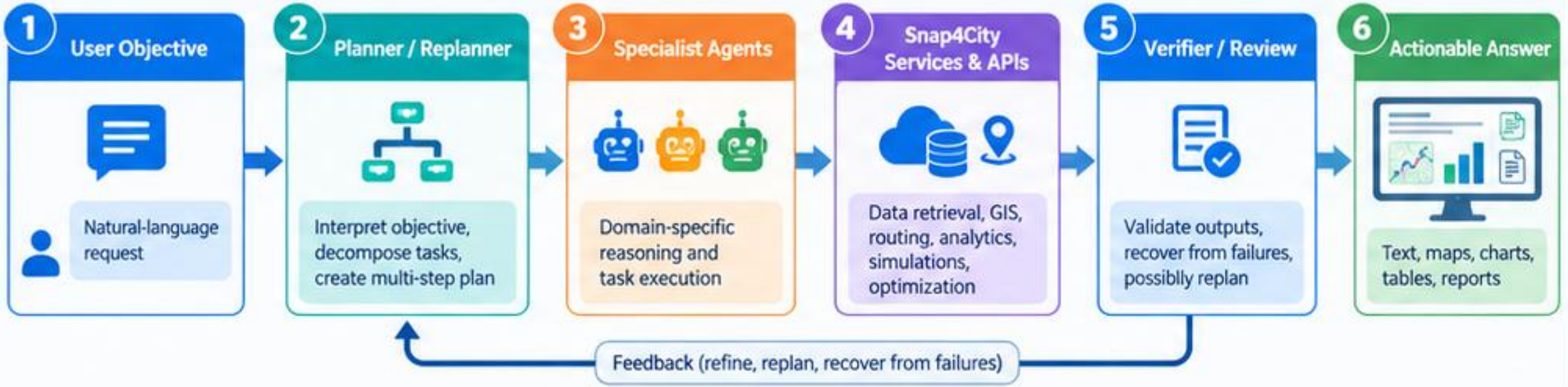
SNAP4CITY

- **Private knowledge** — Use your documents and web resources
- **Multi-user / multi-organisation** — Secure isolation and flexible deployment
- **Traceable answers with sources** — Explainable outputs with data sources and justifications

PEOPLE
PLACES
PLANET
PROSPERITY



System Architecture & Workflow



Knowledge & Expertise Layer

RAG with private collections

PDFs, documents, slides, images, code, web pages

Domain-customisable expertise

City, mobility, energy, environment, tourism, ...

Multilingual support

EN IT FR ES

and more...

Web search for additional resources

External knowledge when needed

Snap4City / Km4City ontology support

Semantic models, linked data, urban knowledge graphs

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SnapAdvisor evolves with your organisation

Your private resources. Multiple users. Multiple departments.



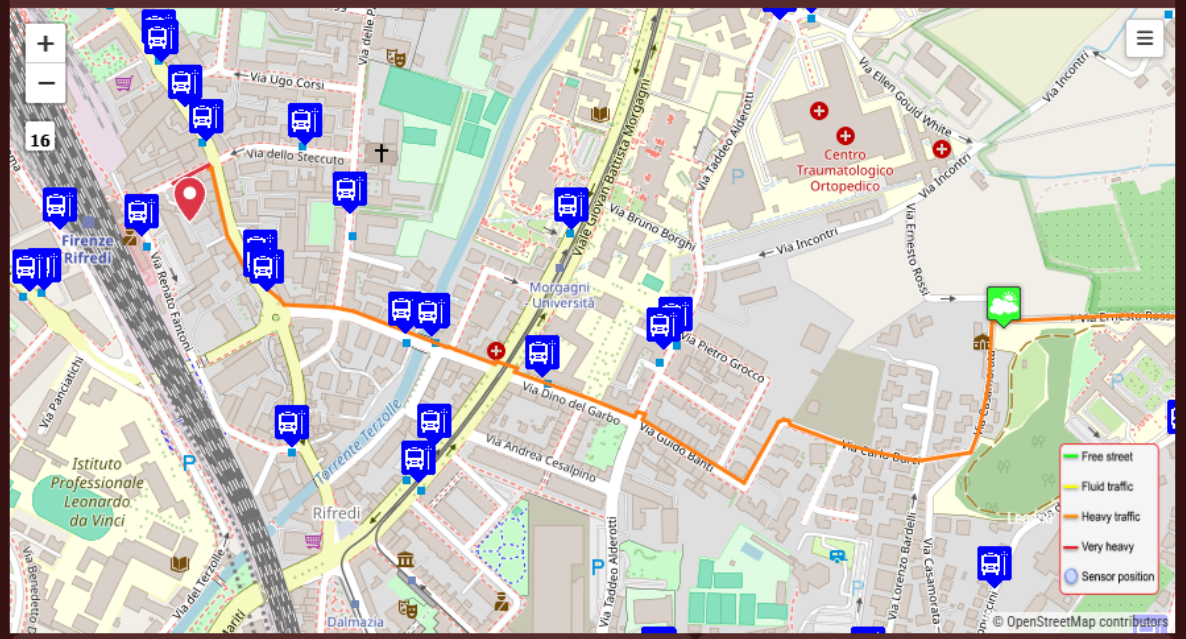
Extend expertise and capabilities with resources you control

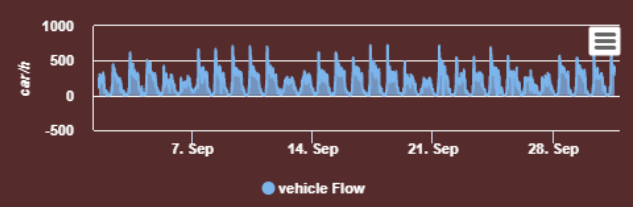
© Snap4City, Nov. 2026

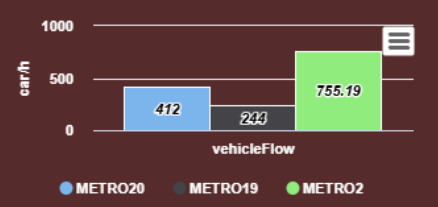
SnapAdvisor / CoPilot: Agentic AI / RAG For Smart City

Conversational tool for Operators and Decision Makers

Tue 20 Oct 12:31:14







Chat

New Chat

verification

Test Prod

Clear Map Clear Bars Clear Time-Trend

verification

PDF chat

Recommendations

- Conduct thorough market research to understand the demand for pizzerias in the area.
- Analyze the competitive landscape by gathering data on existing pizzerias and their popularity.
- Evaluate the financial viability by detailed financial data and projections.
- Assess the location's suitability by gathering data on foot traffic, nearby businesses, and accessibility.

By addressing these uncertainties, a more informed decision can be made regarding the advisability of opening a pizzeria in Via dello Steccuto, Florence.

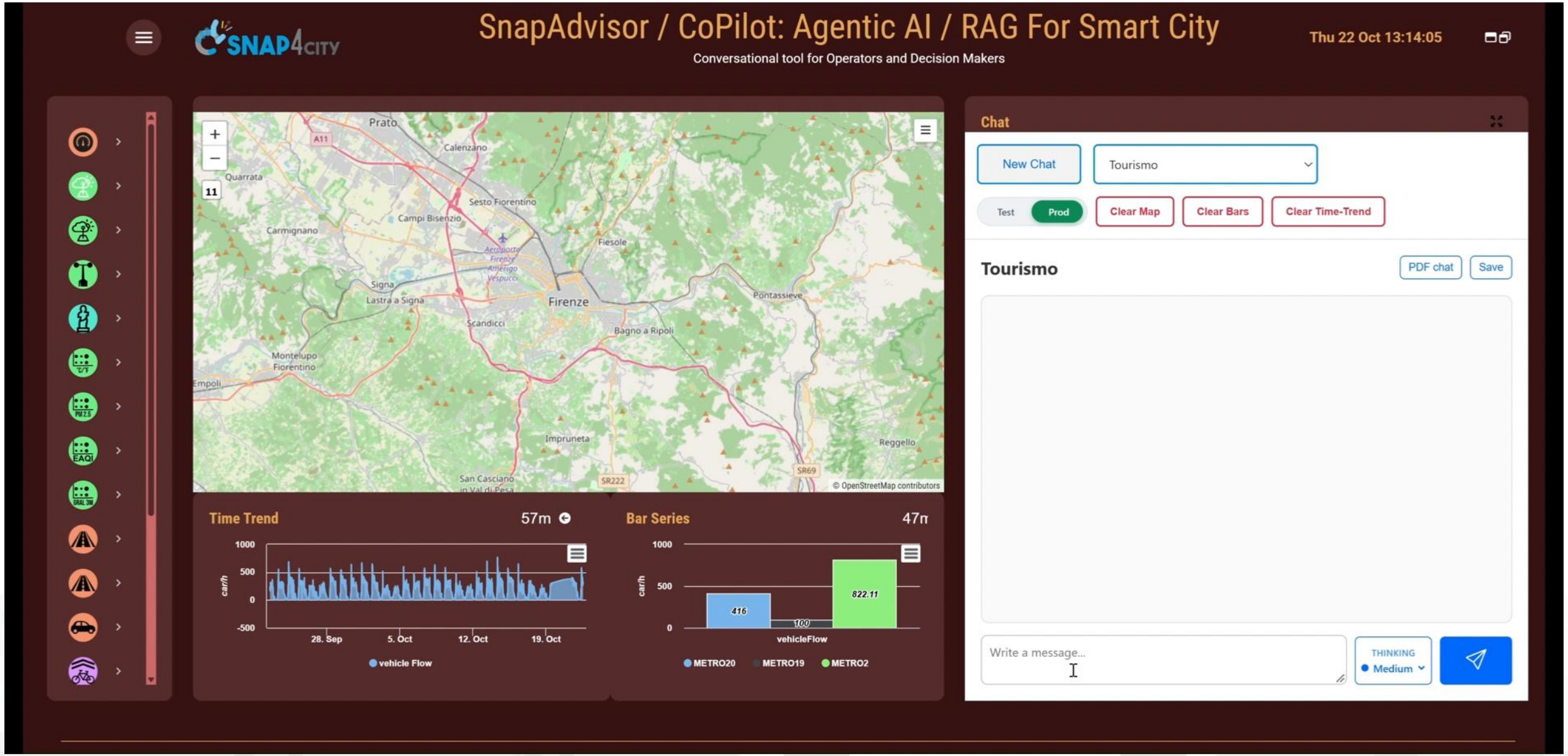
Is it advisable to open a pizzeria in via dello steccuto, florence?

P 0% N 100% Neg 0%

Location Peso 20%

please produce a decision support graph to open a pizzeria in via dello steccuto, florence

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SnapAdvisor / CoPilot: Agentic AI / RAG For Smart City
Conversational tool for Operators and Decision Makers
Thu 22 Oct 13:14:05
Prato
Calenzano
Quarrata
Sesto Fiorentino
Campi Bisenzio
Carmignano
Fiesole
Signa
Lastra a Signa
Firenze
Scandicci
Bagno a Ripoli
Pontassieve
Montelupo Fiorentino
Impruneta
Reggello
San Casciano in Val di Pesa
© OpenStreetMap contributors
Time Trend
57m
vehicle Flow
Bar Series
47m
416
100
822.11
vehicleFlow
METRO20
METRO19
METRO2
Chat
New Chat
Tourismo
Test
Prod
Clear Map
Clear Bars
Clear Time-Trend
Tourismo
PDF chat
Save
Write a message...
THINKING
Medium

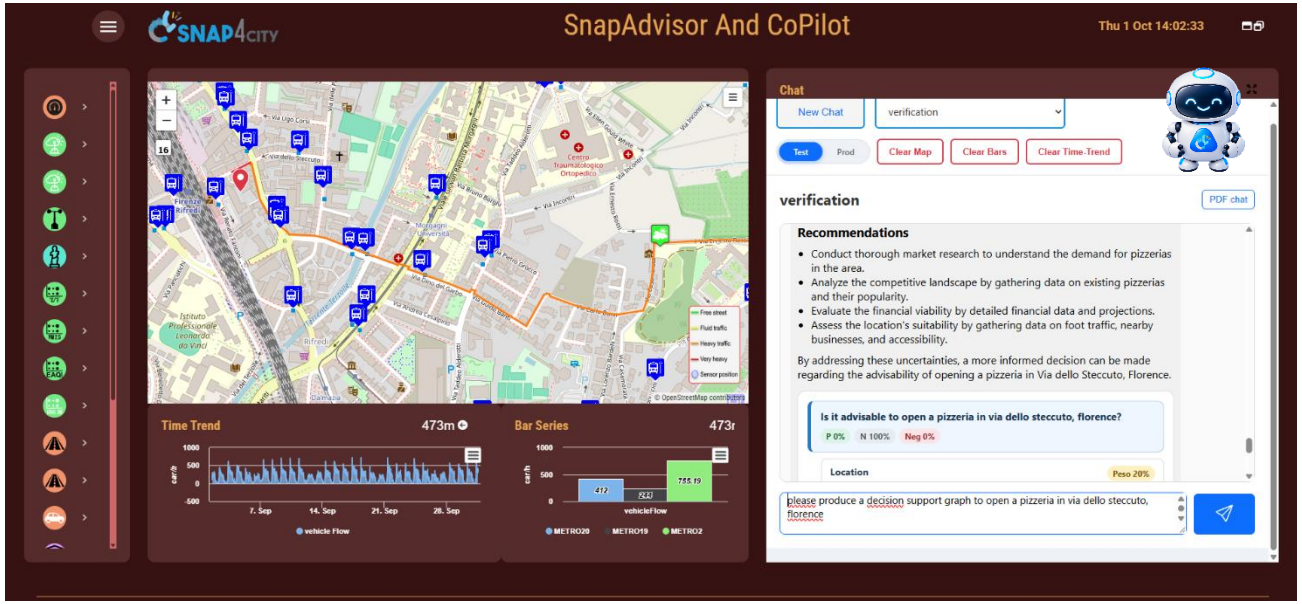
UNIVERSITÀ DEGLI STUDI FIRENZE

DINFO DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB
DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB

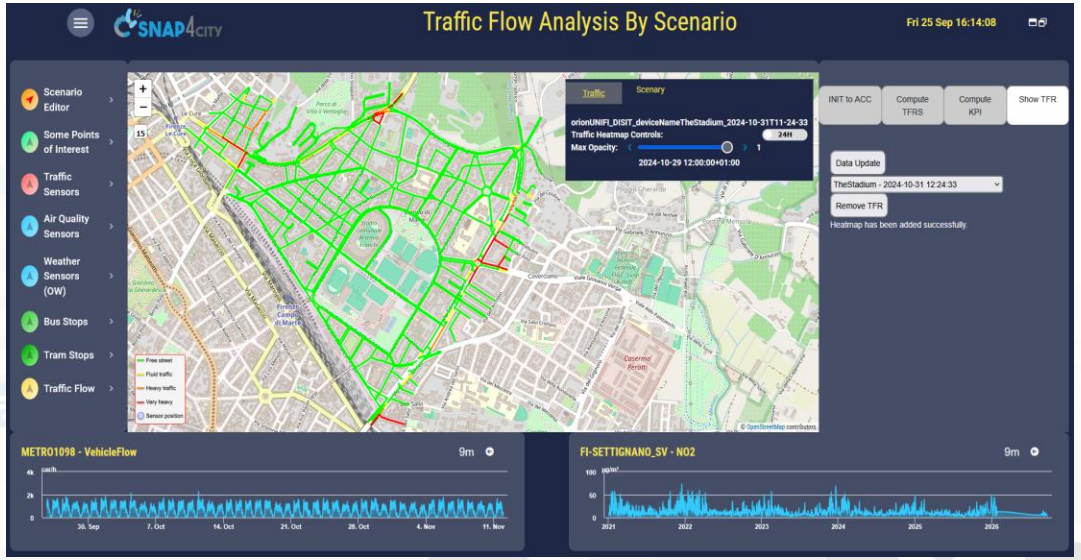
Mobility & Transport
- Routing
- Traffic flow
- Public transport
- Simulation, KPI computation
- Optimization

SNAP4CITY KM4CITY





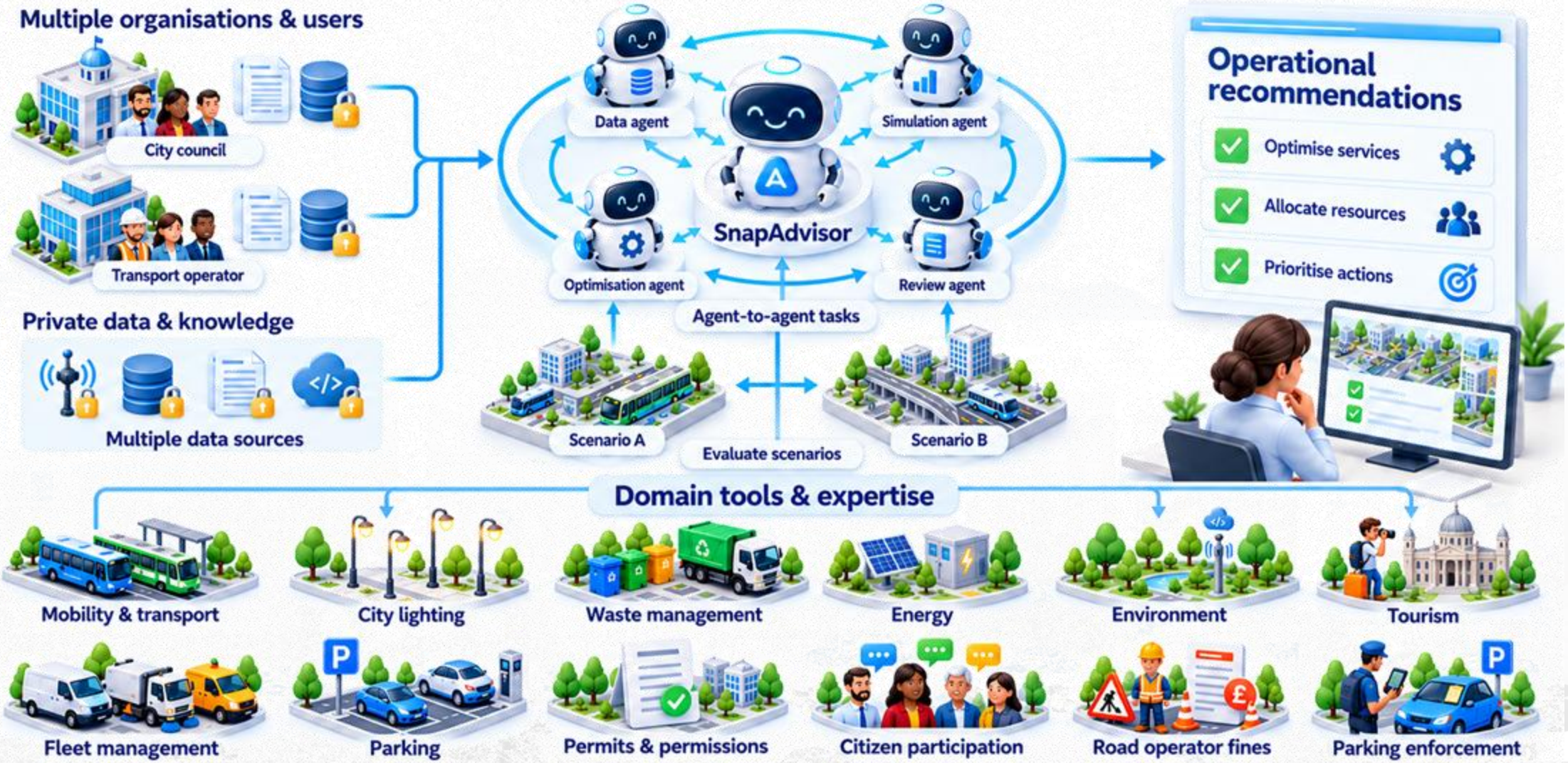




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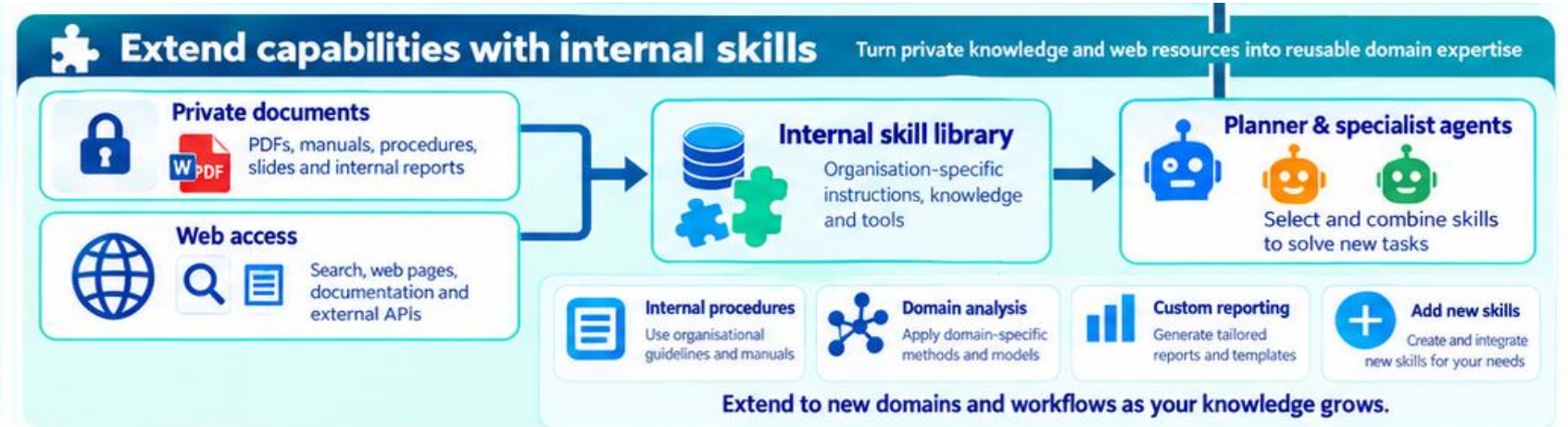
SnapAdvisor: tools and expertise across city services

Autonomous scenario evaluation and actionable operational recommendations



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Skill Packages



- Multiple and pluggable Skills, for different users and teams
- Full Custom Skills
- Integrate internal skills with web access, when needed



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DSS, Decision Support Systems, produzione di suggerimenti

- Costruisci un modello DSS per scegliere fra aprire una gelateria e aprire un edicola in via Gioberti a Firenze mostra criteri, pesi, punteggi e fonti.
- Un concerto da 40.000 persone è previsto presso il Mandela Forum domenica 25 novembre Usa il DSS per valutare i rischi per mobilità, sicurezza e servizi urbani.
- Usa il DSS per scegliere fra due siti per un nuovo parcheggio Via Carlo Burci Firenze e Via delle Panche Firenze . Considera accessibilità, costo, impatto ambientale e vicinanza al trasporto pubblico.
- Usa il DSS per scegliere quale di questi interventi attuare prima zona parco Cascine a Firenze ridurre la congestione, migliorare l'illuminazione, aumentare la raccolta rifiuti. Spiega come stabilisci le priorità
- Usa il DSS per scegliere fra tre interventi per migliorare l'illuminazione di piazza Dalmazia firenzenuove lampade, aumento della potenza delle lampade esistenti, illuminazione adattiva
- please produce a decision support graph to open a pizzeria in via dello steccuto, florence
- Sabato c'è un concerto da 40.000 persone a Firenze stadio. Valuta i rischi.
- valuta tramite il dss se conviene aprire una gelateria vicino al duomo di Firenze
- Che tipo di supporto alle decisioni mi puoi fornire
- Valutami tramite il dss se conviene aprire un edicola a S. Marta Firenze

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SIMULATIONS, what if, optimization, vari agenti

- Which SUMO scenarios can I simulate?
- Which traffic scenarios in Florence are available for simulating traffic light optimization under different traffic load levels?
- Start a new traffic simulation for the mamotlo1 scenario. please make a simulation of Mamotlo1
- What is the status of the simulations for the mamotlo1?
- List the completed bari-iot-simulation simulations whose indicators I can view.
- How many vehicles were simulated in the scenario mamotlo1 for Simulation_20261020085145
- Retrieve the mobility indicators for simulation Simulation_20251205150733 of scenario bari-iot-simulation, including the minimum, maximum, and average values for waiting count, waiting time, and time loss.
- Optimize the Liberta-Case1 scenario to improve traffic state, applying at most 4 changes.
- Optimize the StatutoCase1 scenario to reduce CO2, applying at most 8 changes.
- Retrieve the mobility indicators for simulation Simulation_20251205150733 of scenario bari-iot-simulation, including the minimum, maximum, and average values for waiting count, waiting time, and time loss.

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SKILL ADDIZIONALI e competenze personalizzabili, RAG agent

- Che tipo di conoscenze addizionali disponi
- usa la collection snap4city-v1 e fornisci la descrizione di Iot Directory
- metti in una tabella le collection che hai
- quali sono i contenuti della collection Snap4city4dummies
- come esperto che tipo di soluzioni proponi per prepararsi ad eventuali alluvioni in città
- fammi un modello decisionale e provalo per decidere se modificare la viabilità di ponte alla Vittoria a Firenze
- avendo problemi di nettezza fuori dai cassonetti in piazza Giorgini a Firenze che cosa mi consigli come esperto di gestione dei rifiuti mi sembra buono

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SnapAdvisor & Co-Pilot



Natural Language Intelligence
Instant query access to live city metrics, IoT sensors, and GIS layers.

Agentic Decision Support
Autonomous scenario evaluation and actionable operational recommendations.

- Multiple Users, private data and knowledge
- Multiple Agents & Agent to Agents tasks
- Multiple organisations and data sources

Digital Twin Synergy
Seamless integration with 3D models and control rooms.

What-If Simulations
Simulate and optimize, computing KPIs

GDPR & Security Shield
Privacy compliance with full on-premise cloud deployment.



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SnapAdvisor is for

City operators

Monitor conditions, compare places or periods, investigate anomalies and calculate routes.



Decision makers

Collect evidence, assess scenarios and compare proposed interventions. City Officers, assessor.



Developers

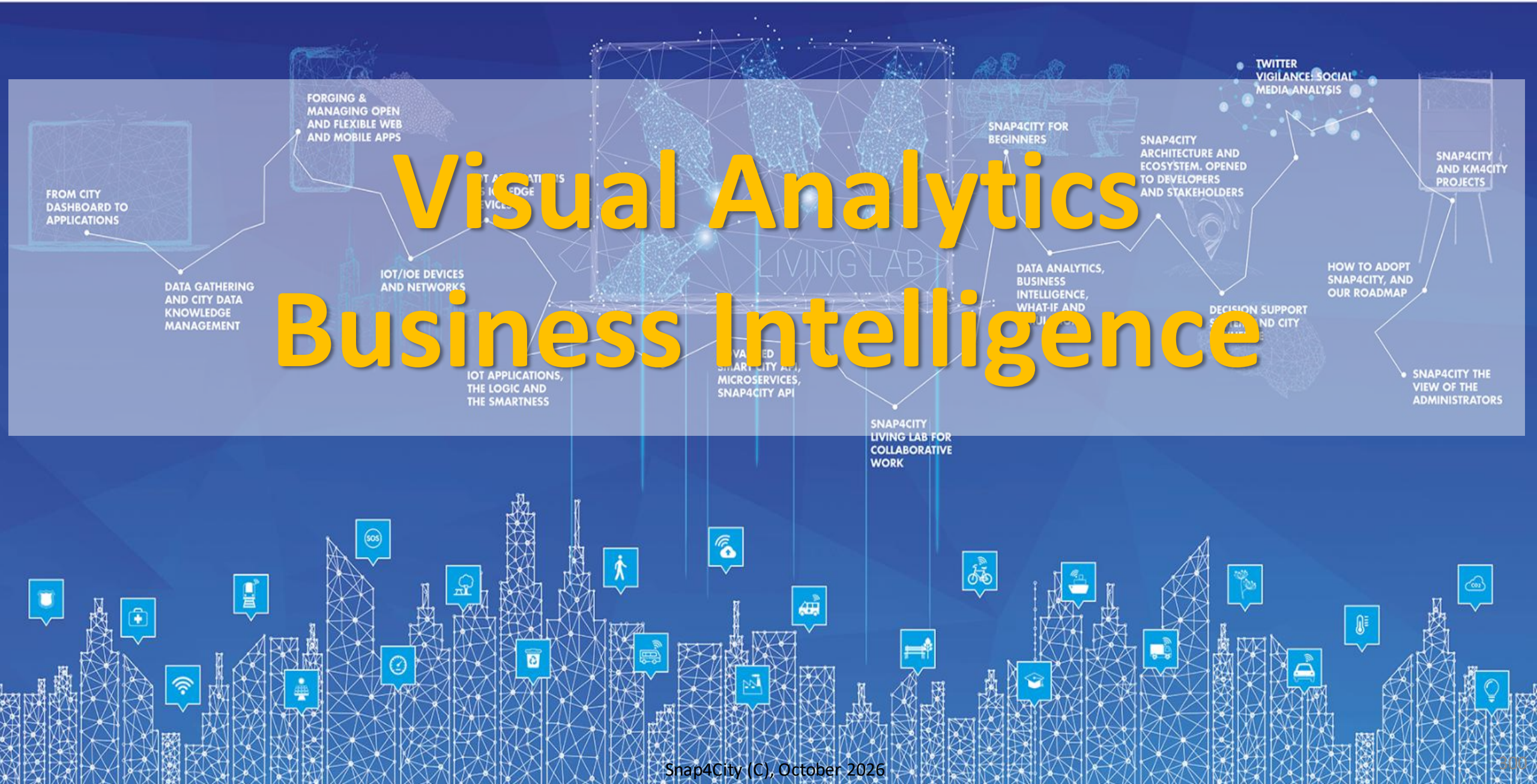
Find documentation, identify APIs and use Snap4City tools to build applications.





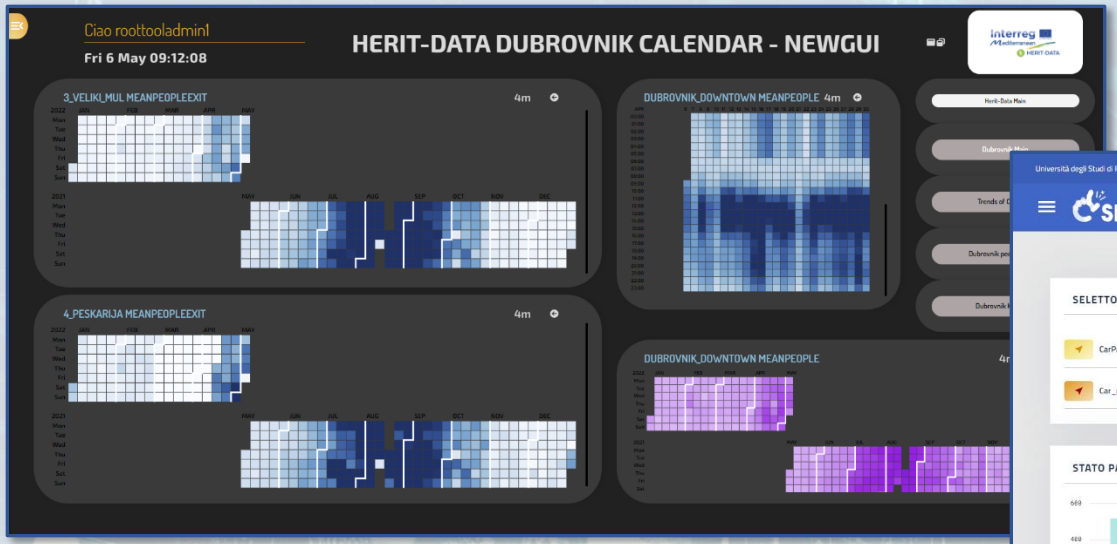
A multilingual interface across mobility, energy, tourism and any other domains, including your private collection of document and info.

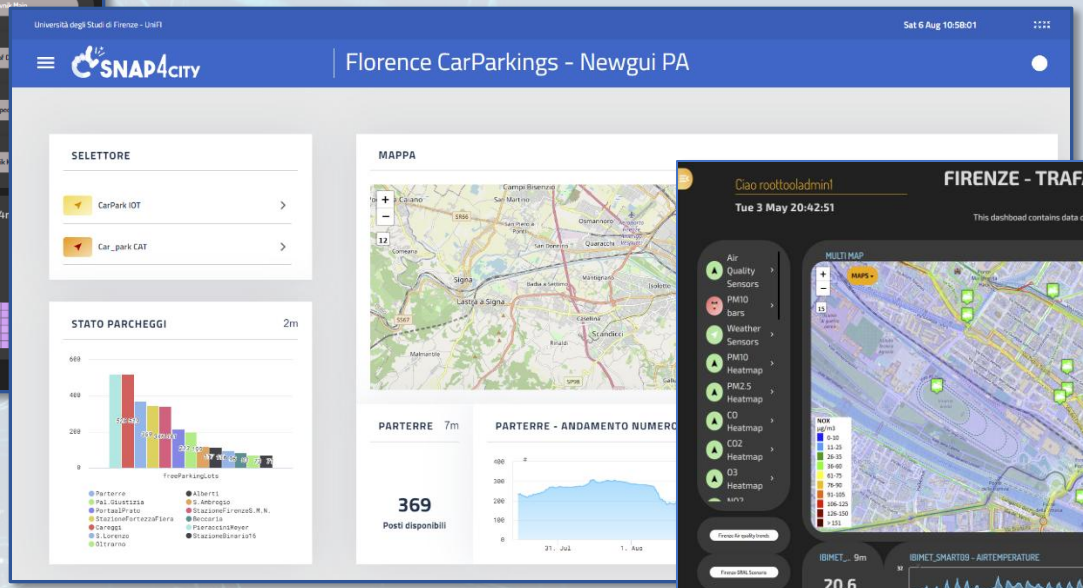
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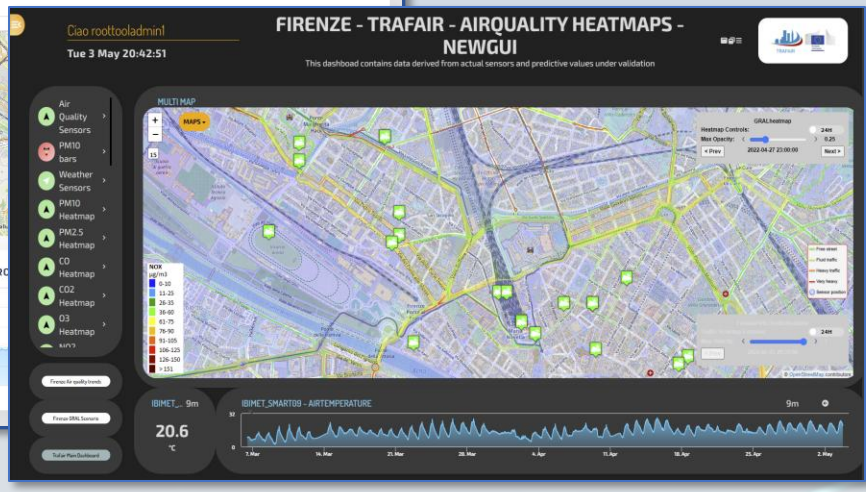


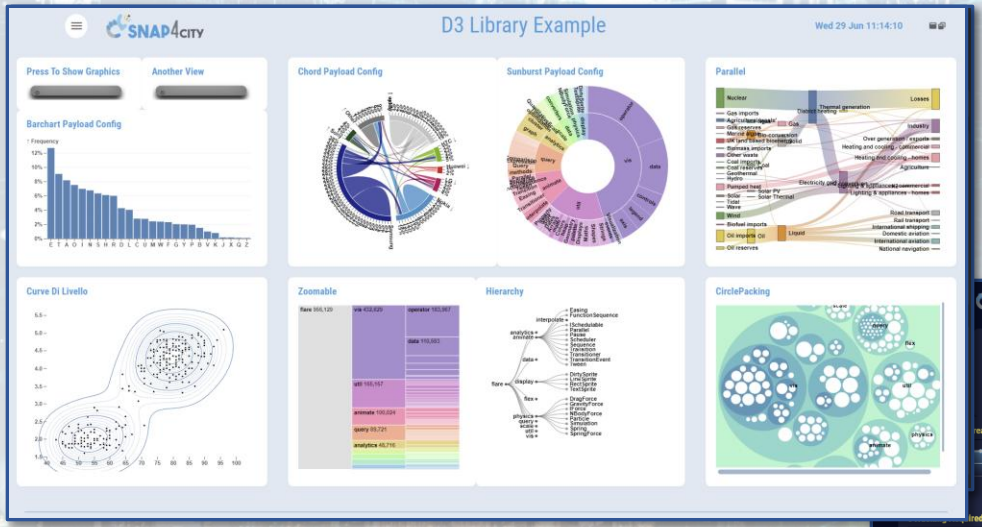
Visual Analytics Business Intelligence

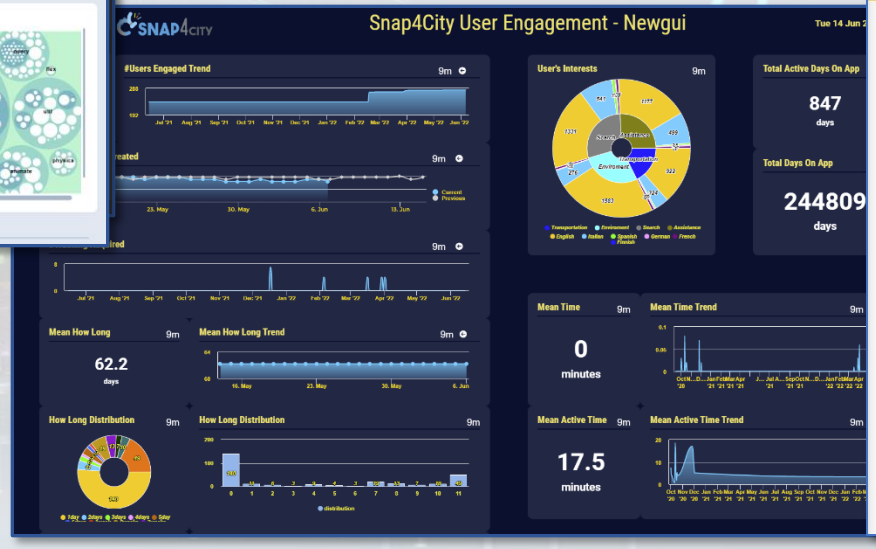
Different Themes

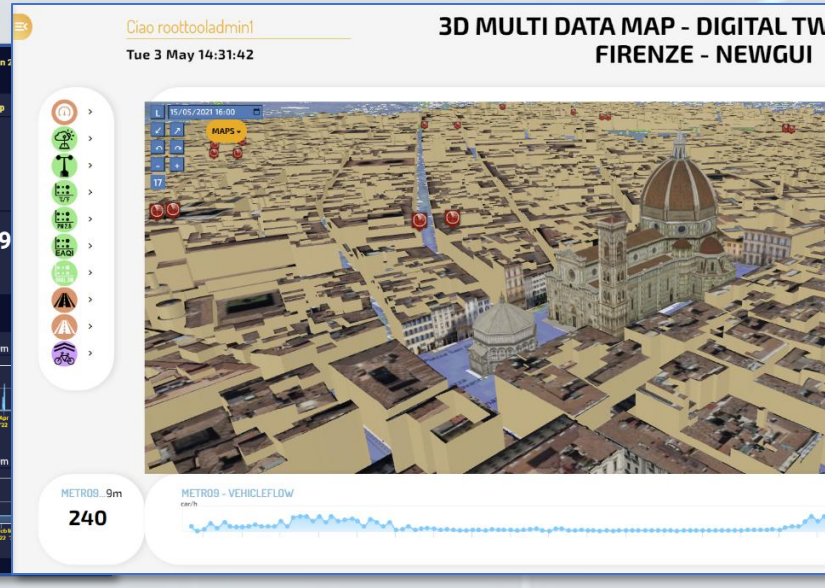










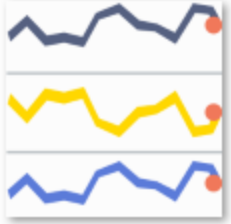


New styles/themes can be developed by specializing a few files from open source

https://www.snap4city.org/793

Visual Representations


Sliderwith-multiple-steps-for-KPI


sparklines



kpi


histogram


heatmap


flow-maps


geo-maps

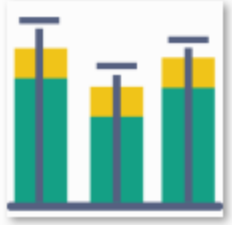

donut-chart

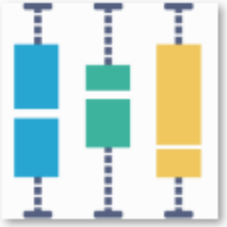

Data-grid


chord


Cone


Bubble-matrix-chart


Bullet


Box-plot


staked-area


Stacked-line-chart


Stacked-combinational-Chart


spider-maps


Sequence-Sunbur


Pivot


pie-chart-1


Pareto-chart


radar

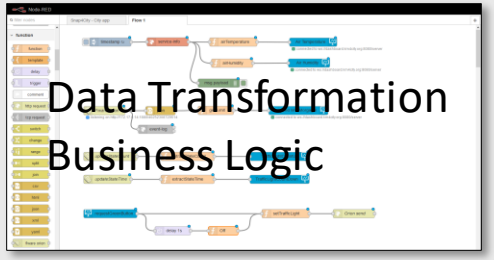

Bubble-maps


waterfall


Sunburst


Sankey

Dashboard Builder: Development



Data Transformation
Business Logic

IOT Applications



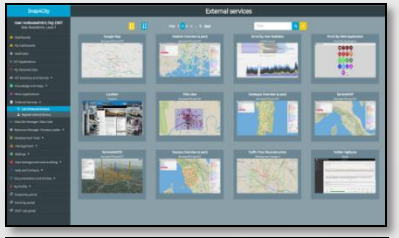
Knowledge and Storage
Data from the Field and
City + MyKPI ++

Widget Collection





Micro
Applicat
ions

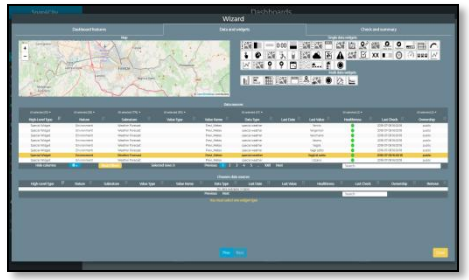


External
Services



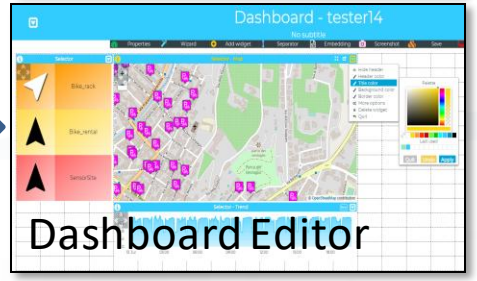
Custom
Widgets/
Synoptics

Dashboard Wizard



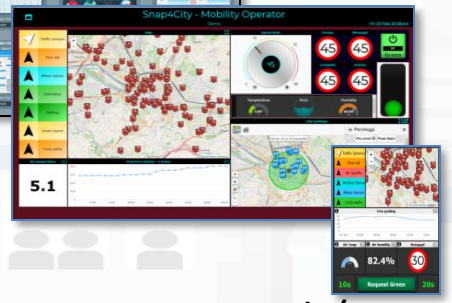
Create, save, load,
delegate, grant access,
change ownerhip





Dashboard Editor





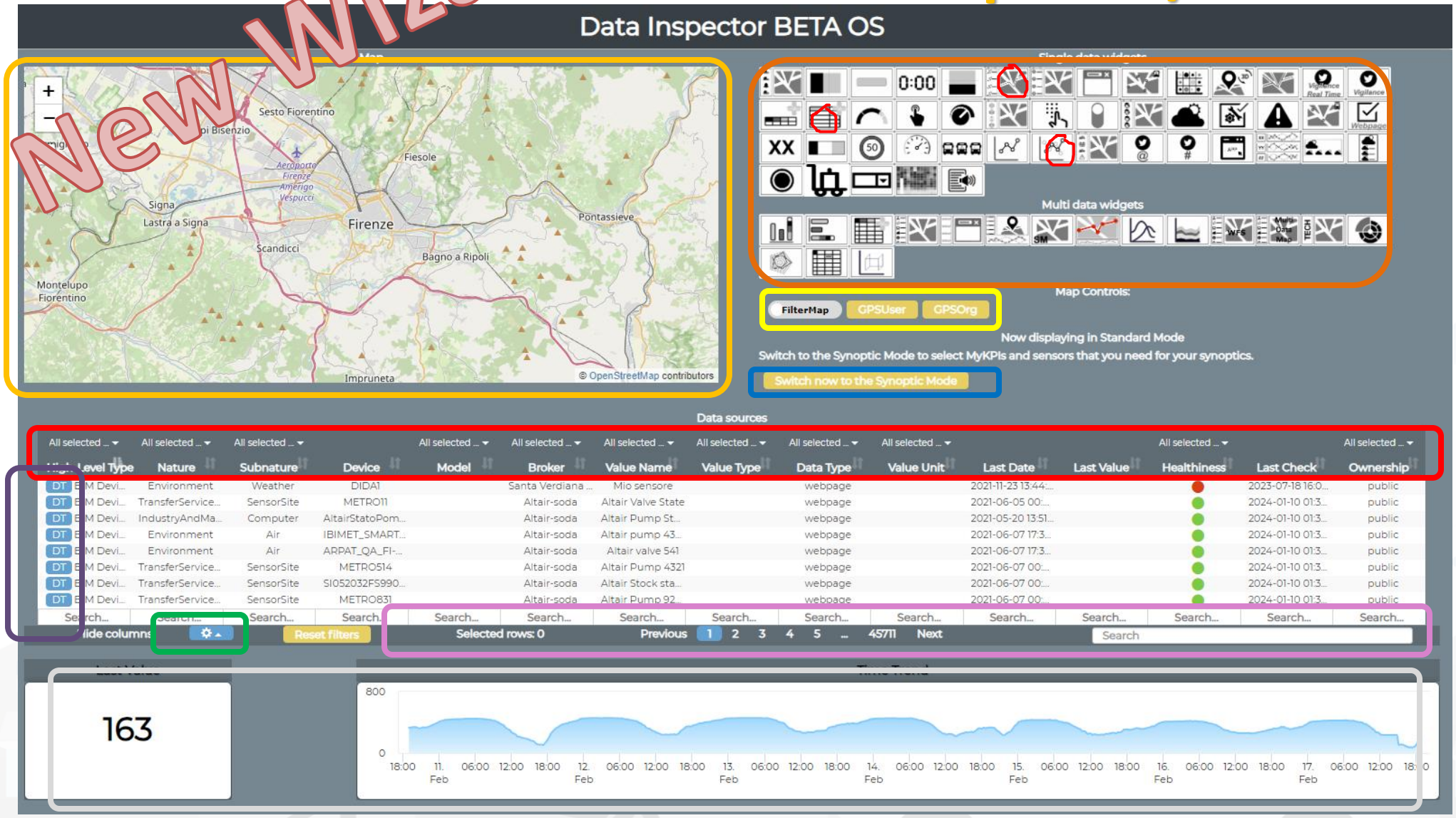
Public
Dashboard
Collection

My Own Dash/App



New Data Inspector/Wizard

New Wizard



Filtering/Searching for individual fields (even for some fields not displayed as geographic coordinates)

Geographic Filtering

Text Search on all fields

Menu for choosing the fields to display in the table

View on Map(via PREVIEW)

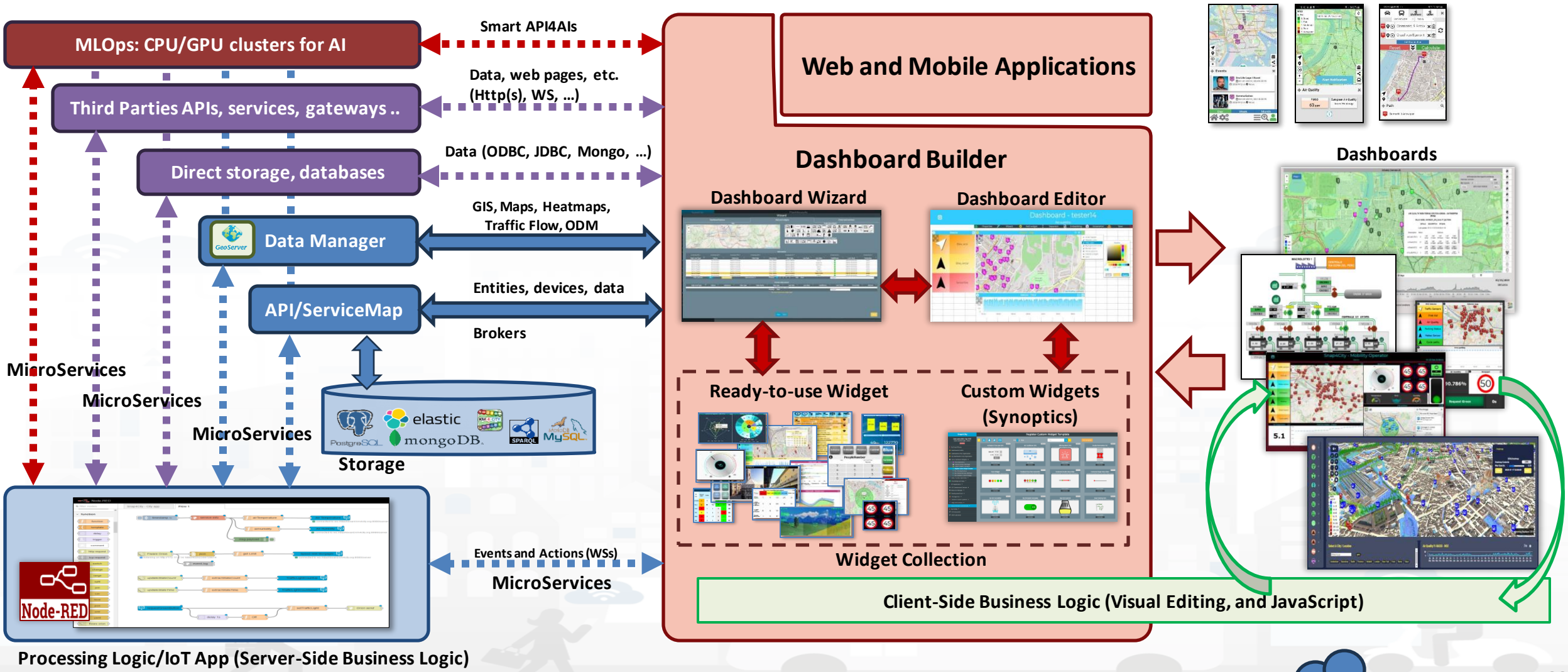
Data and Trend visualization

Opening Digital Twin

Pass to Synoptic mode

Select the graph representation

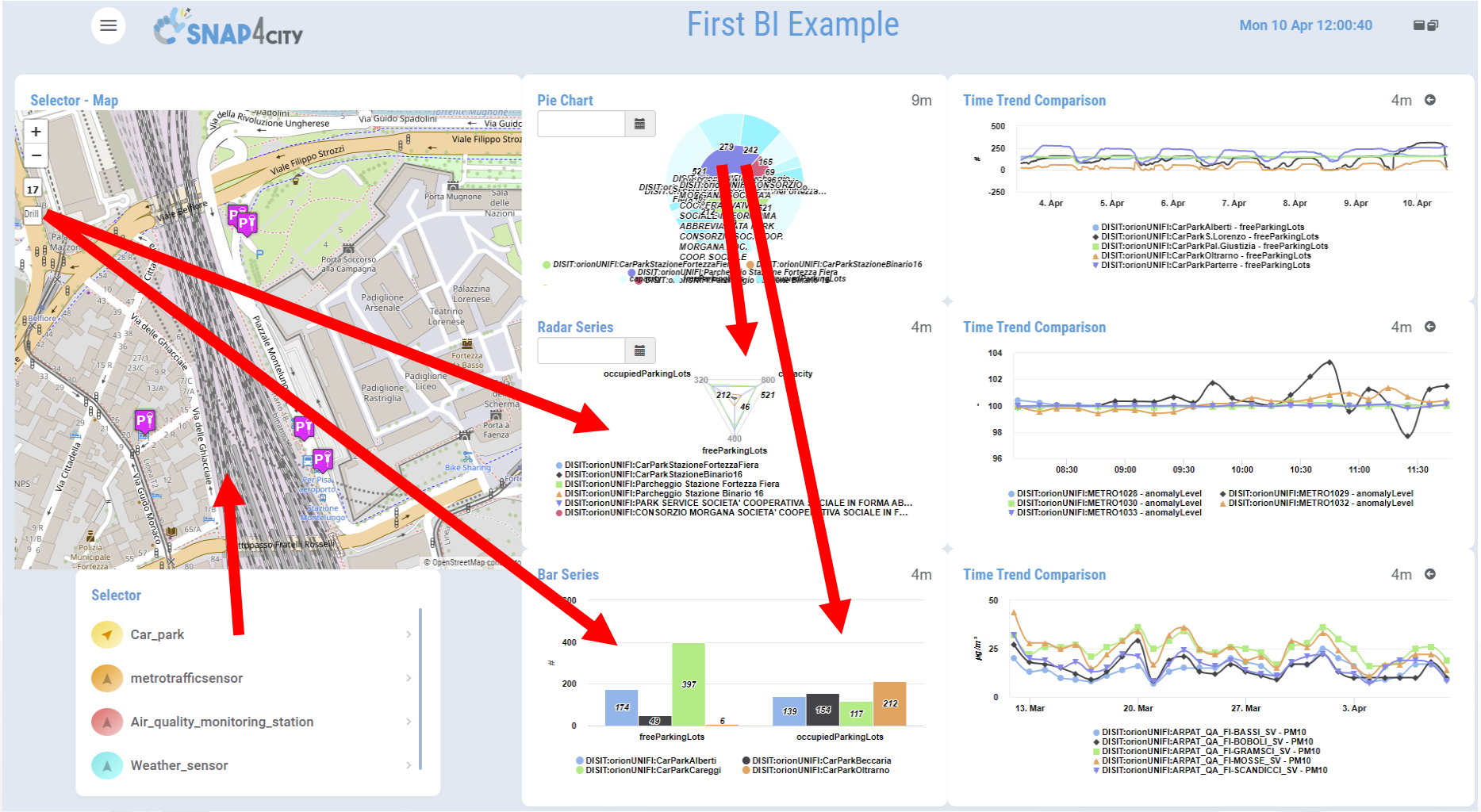
How the Dashboards / Apps Exchange data (2024/8)



Example: From Map to Graphs (spatial drill down)

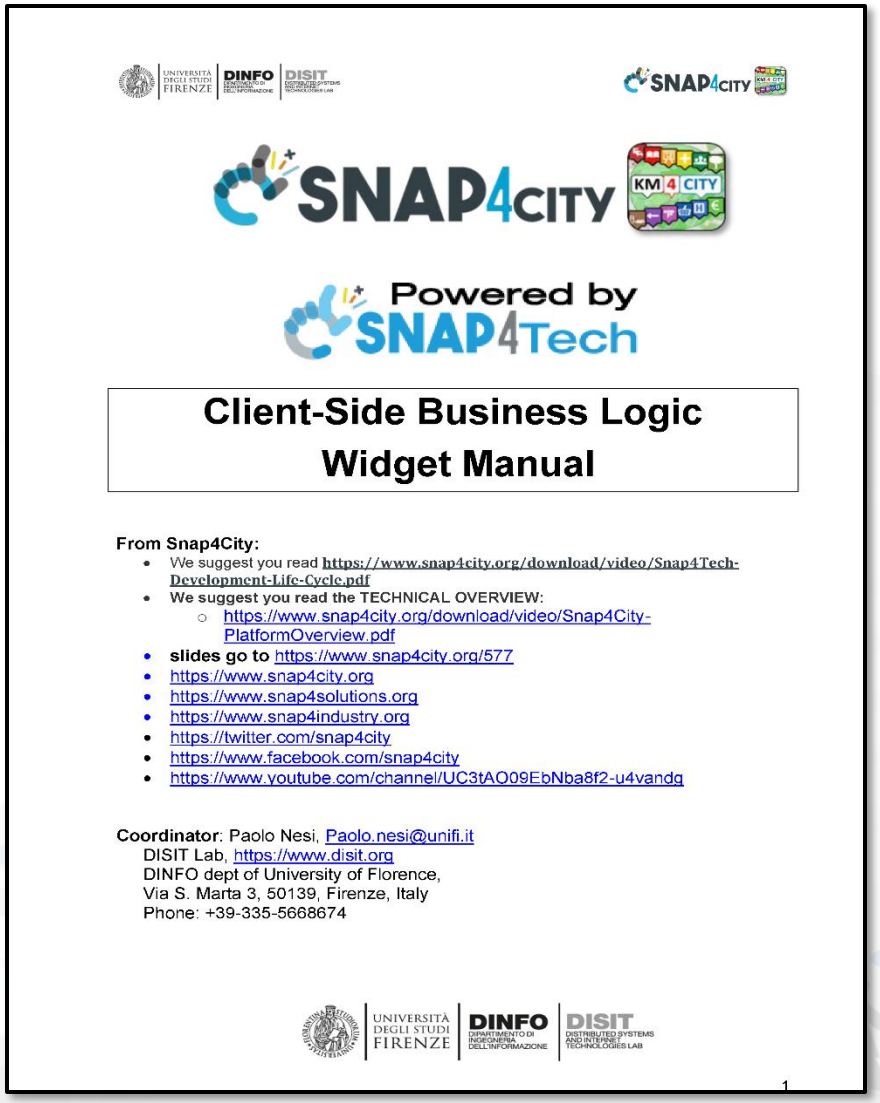
1) Select the area of interest on map
2) Select the sensors kind of interest
3) Drill down on map

4) The JavaScript CSBL on Map will send data to the programmed Widgets. In this case, arrowed in RED



CSBL

Client Side Business Logic



Powered by SNAP4Tech

Client-Side Business Logic Widget Manual

From Snap4City:

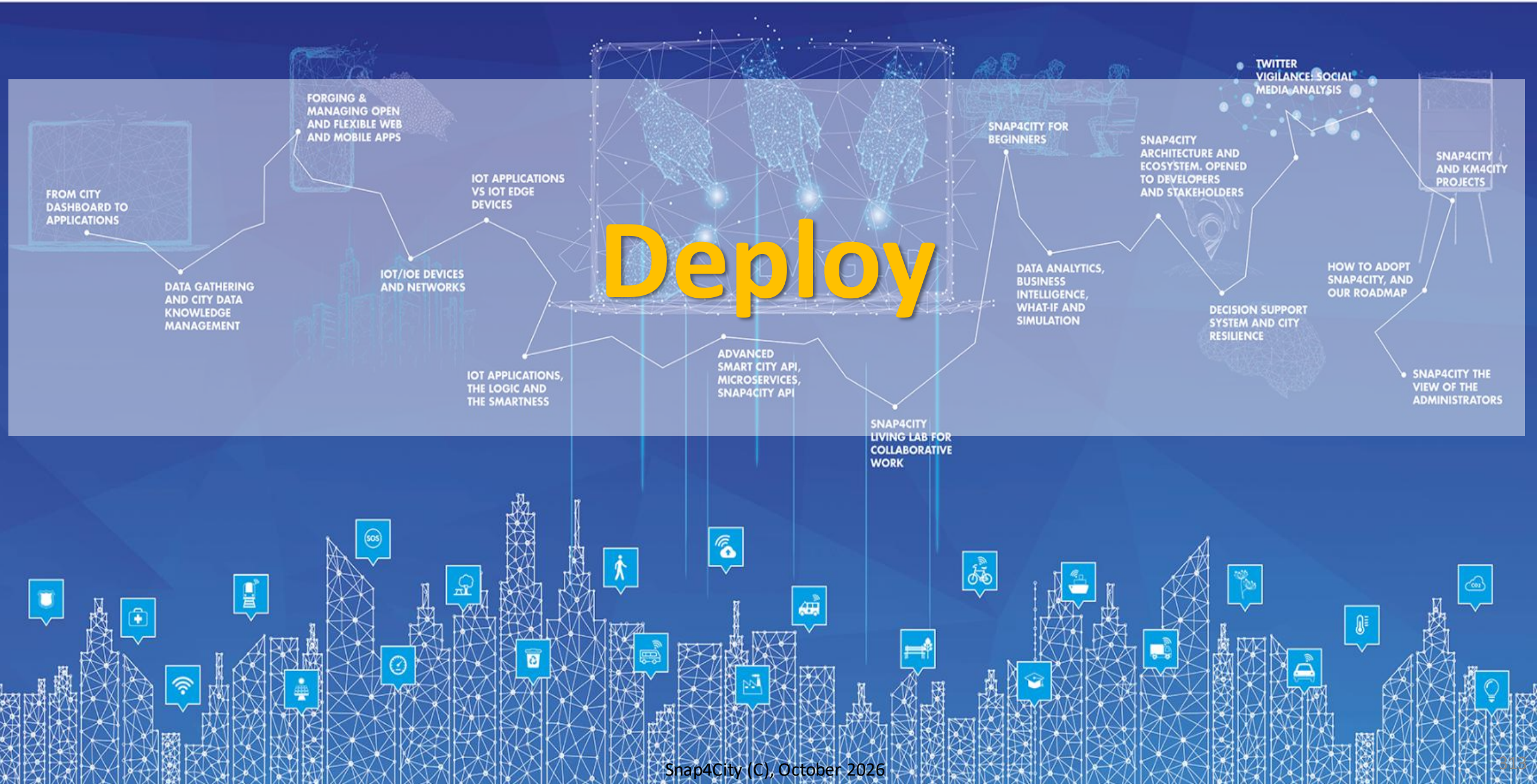
- We suggest you read **https://www.snap4city.org/download/video/Snap4Tech-Development-Life-Cycle.pdf**
- **We suggest you read the TECHNICAL OVERVIEW:**
  - https://www.snap4city.org/download/video/Snap4City-PlatformOverview.pdf
- **slides go to** https://www.snap4city.org/577
- https://www.snap4city.org
- https://www.snap4solutions.org
- https://www.snap4industry.org
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city
- https://www.youtube.com/channel/UC3tAQ09EbNba8f2-u4vandg

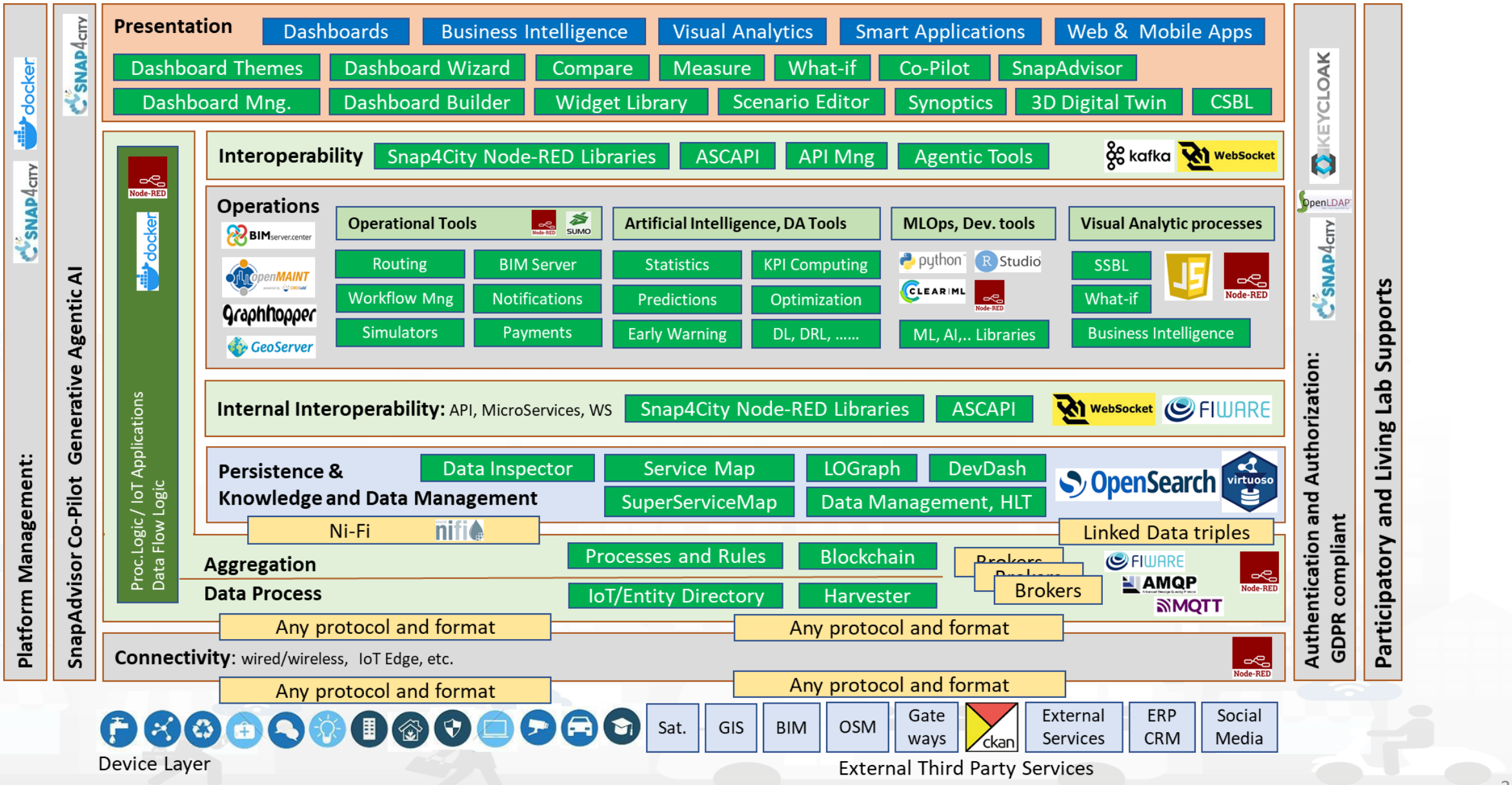
Coordinator: Paolo Nesi, Paolo.nesi@unifi.it
DISIT Lab, https://www.disit.org
DINFO dept of University of Florence,
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Phone: +39-335-5668674

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https://www.snap4city.org/download/video/ClientSideBusinessLogic-WidgetManual.pdf

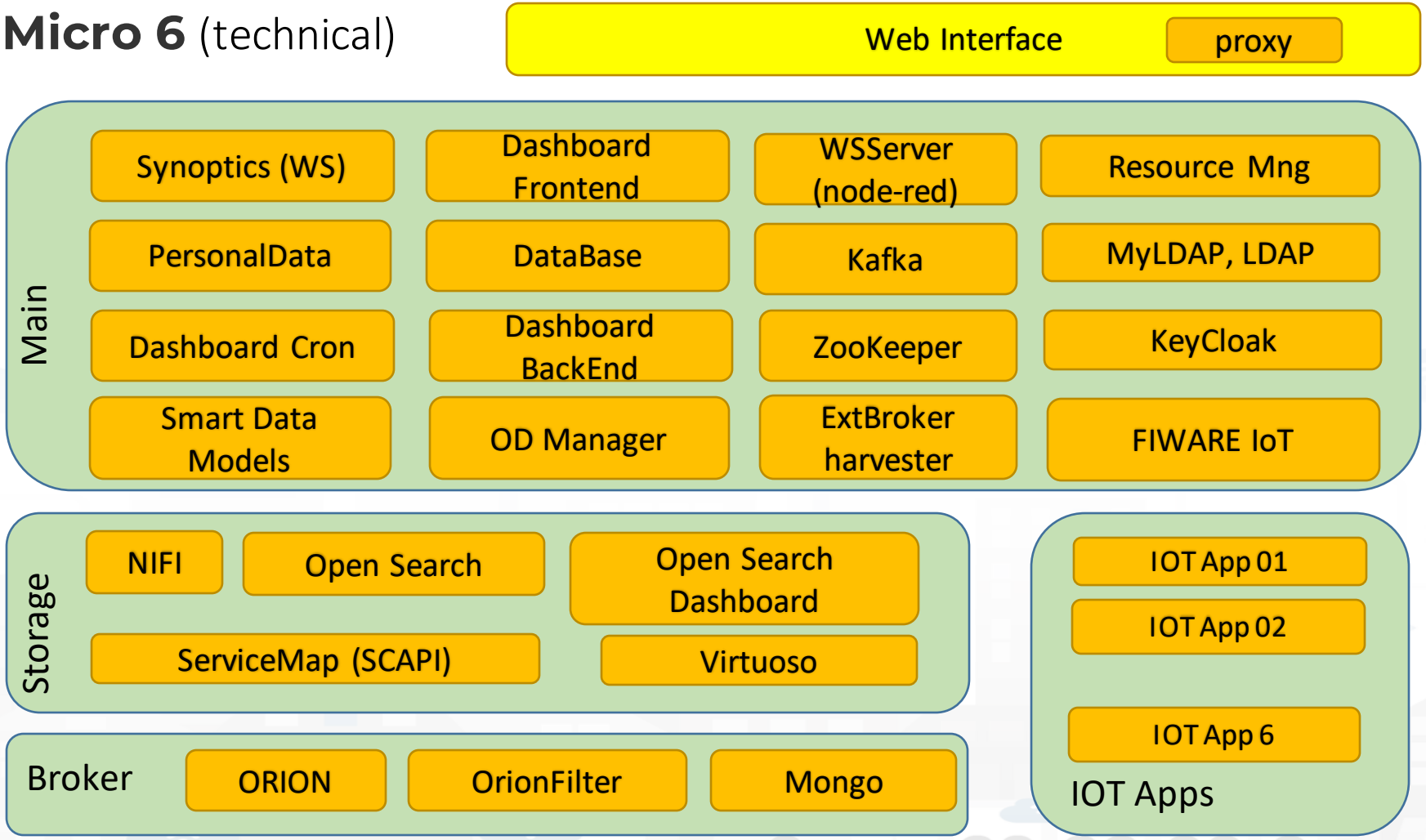
SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES



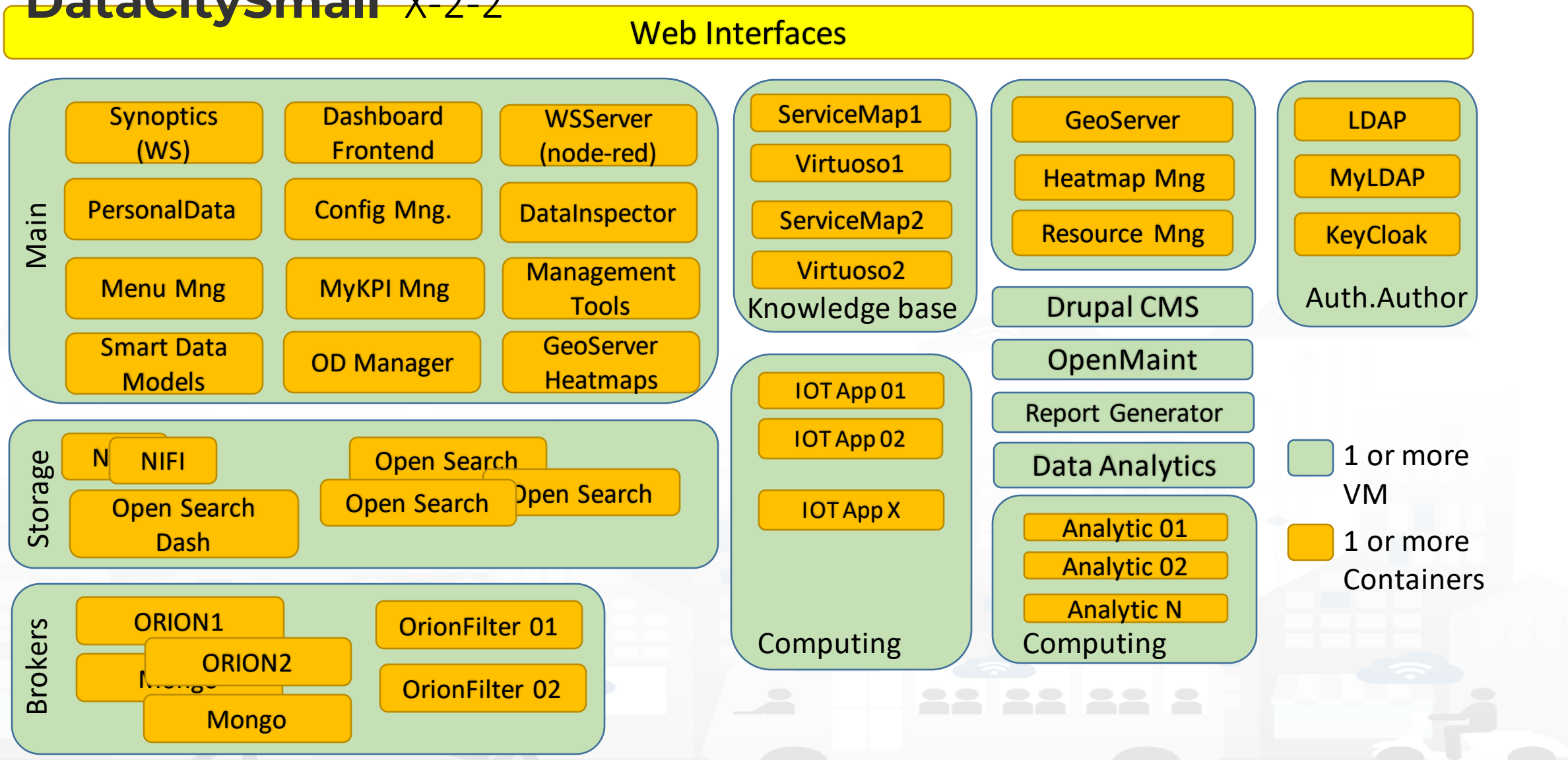

Platform Management:
SnapAdvisor Co-Pilot Generative Agentic AI
Presentation
Dashboards
Business Intelligence
Visual Analytics
Smart Applications
Web & Mobile Apps
Dashboard Themes
Dashboard Wizard
Compare
Measure
What-if
Co-Pilot
SnapAdvisor
Dashboard Mng.
Dashboard Builder
Widget Library
Scenario Editor
Synoptics
3D Digital Twin
CSBL
Proc.Logic / IoT Applications Data Flow Logic
Interoperability
Snap4City Node-RED Libraries
ASCAPI
API Mng
Agentic Tools
kafka
WebSocket
Operations
Operational Tools
Artificial Intelligence, DA Tools
MLOps, Dev. tools
Visual Analytic processes
Routing
BIM Server
Statistics
KPI Computing
Workflow Mng
Notifications
Predictions
Optimization
Simulators
Payments
Early Warning
DL, DRL, ...
ML, AI,.. Libraries
SSBL
What-if
Business Intelligence
Internal Interoperability: API, MicroServices, WS
Snap4City Node-RED Libraries
ASCAPI
WebSocket
FIWARE
Persistence & Knowledge and Data Management
Data Inspector
Service Map
LOGraph
DevDash
SuperServiceMap
Data Management, HLT
OpenSearch
virtuoso
Ni-Fi
Linked Data triples
Aggregation
Data Process
Processes and Rules
Blockchain
IoT/Entity Directory
Harvester
Brokers
FIWARE
AMQP
MQTT
Any protocol and format
Any protocol and format
Connectivity: wired/wireless, IoT Edge, etc.
Any protocol and format
Any protocol and format
Device Layer
Sat.
GIS
BIM
OSM
Gate ways
ckan
External Services
ERP CRM
Social Media
External Third Party Services
Authentication and Authorization: GDPR compliant
KEYCLOAK
OpenLDAP
Participatory and Living Lab Supports

Micro 6 model

Micro 6 (technical)



DataCitySmall X-2-2



Parte di Marco Fanfani da martedi prossimo

Data Models, Mobility data spaces
GTFS, ODM, TFR
Km4City ontology
Time series (collini)
Optimization with DRL (ale)
MLOps (nathan)