

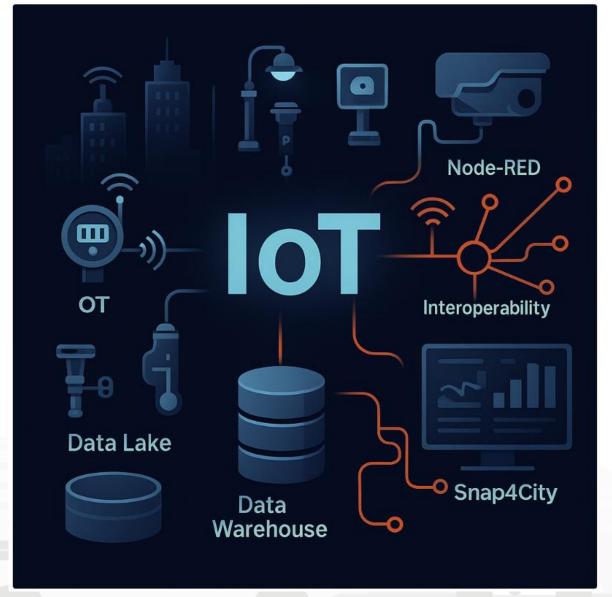




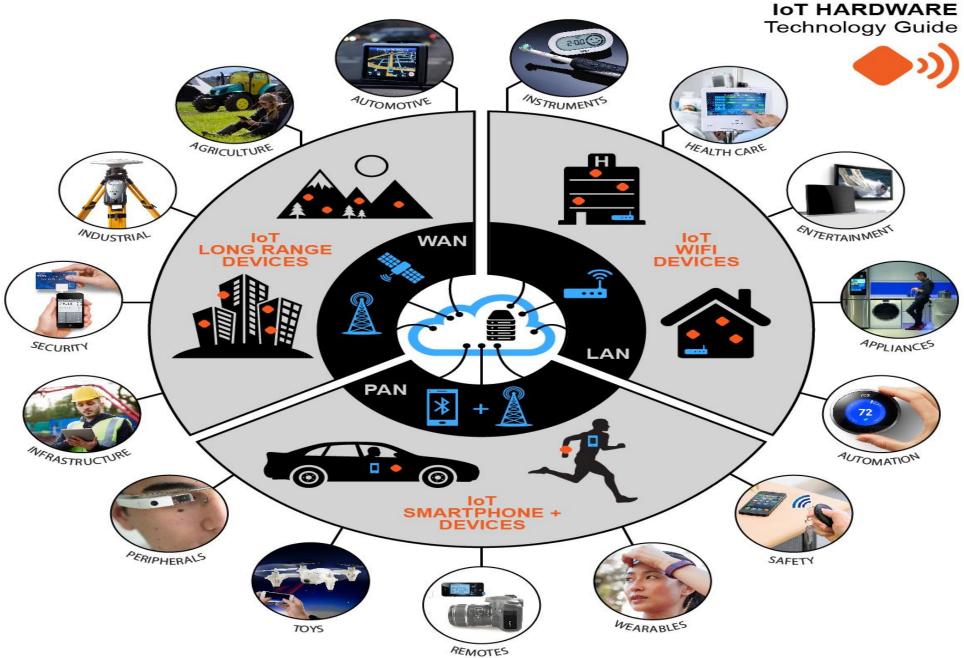


From IoT to large architetture and programming on them

Big data archiecture
Paolo Nesi
DISIT Lab, UNIFI
2025





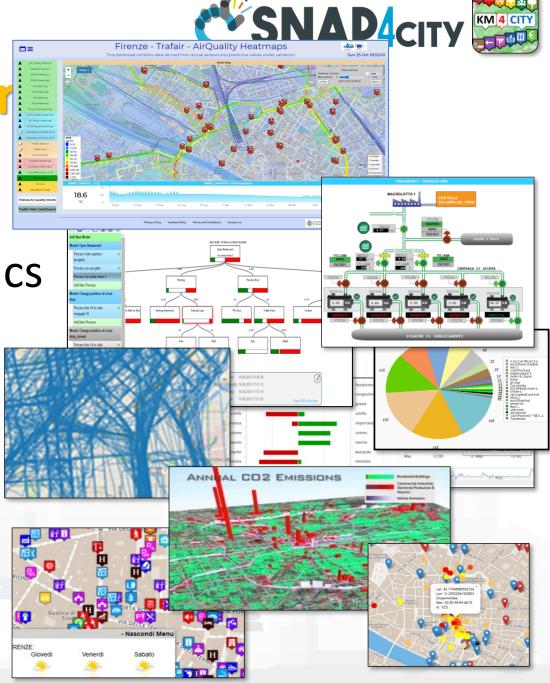




Data Driven Decision Suppor

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







OFFLINE

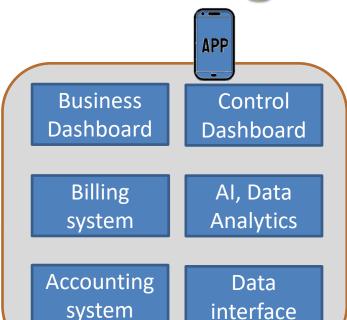






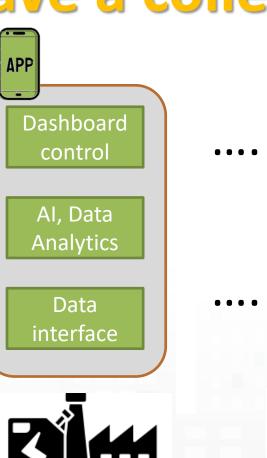


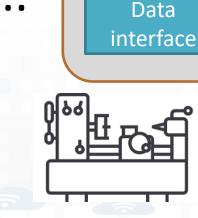
Avoiding to have a collection of verticals



ONLINE





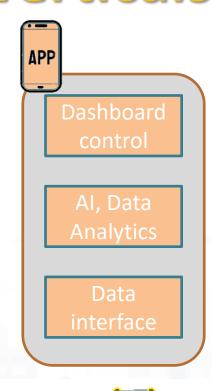


Dashboard

control

AI, Data

Analytics





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
- Commercial aspects

- Patient health record

Static Public (open data)

statistics: accidents, census, votations

- # Accesses to RTZ ZTL Data from Public GOV

Position of commercial activities, POI ry caneras

- Museums
- City services data, almost
- Active services

Personal movements Relationshipsamone · GPS traces Trading, sales people

Consumption of energy, gas User Behaviour social media

Contributions banking

- Personal traffic
- Position of cars
- Position of taxi
- Position of CarSharing ...

- Info traffico
- video camere Info weather
- Info environment
- Status of the queue at Museums earthquake data
- parking

Stato accessialla 271 Stato dei servizi

Real time public (open data)

Real time private

High Level Types

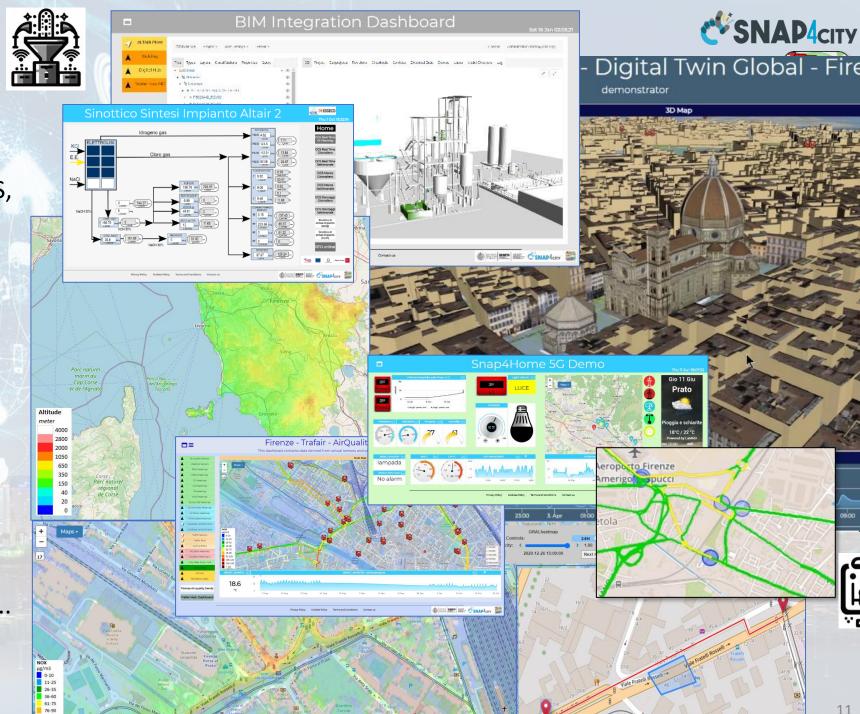
Snap4City (C), October 2025

- 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, ...









Standards and Interoperability

SNAP4city

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















IOT Device





Entity: IOT Device

Sends a message

Message (timestamp: 02-04-2020 at

10:30,

Temperature: 29.34,

Humidity: 35

- 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

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

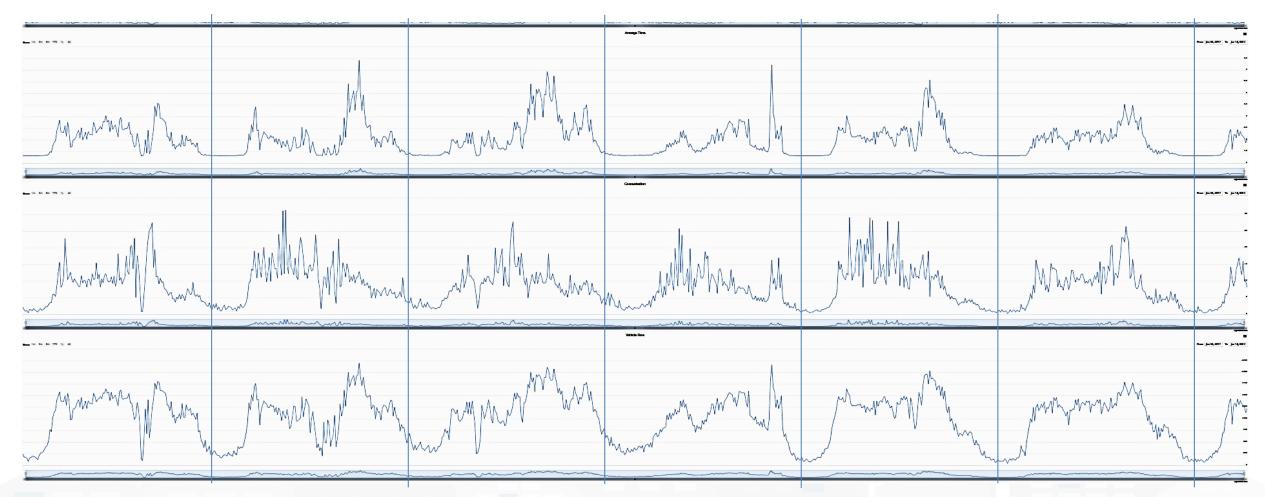












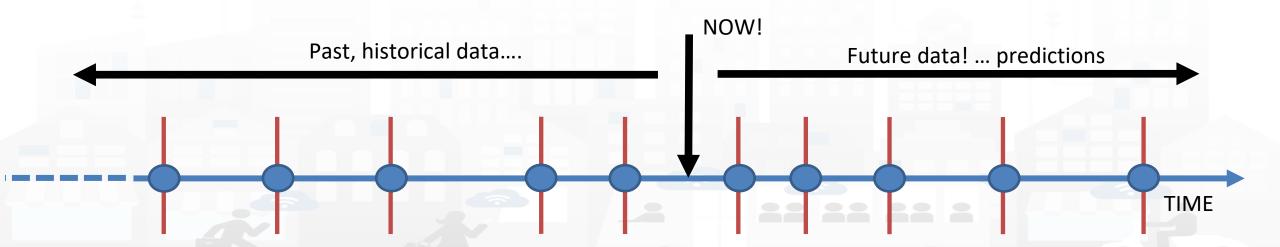
Day by day traffic flow, on the week data from 3 sensors





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,...







Color for missed

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

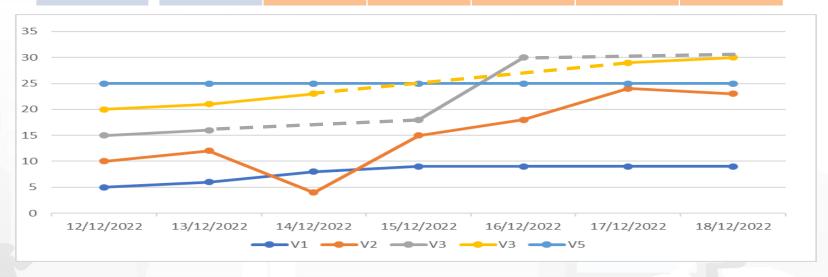
- valid in all messages on graphs
- With holes in tables

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

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	nulí	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.















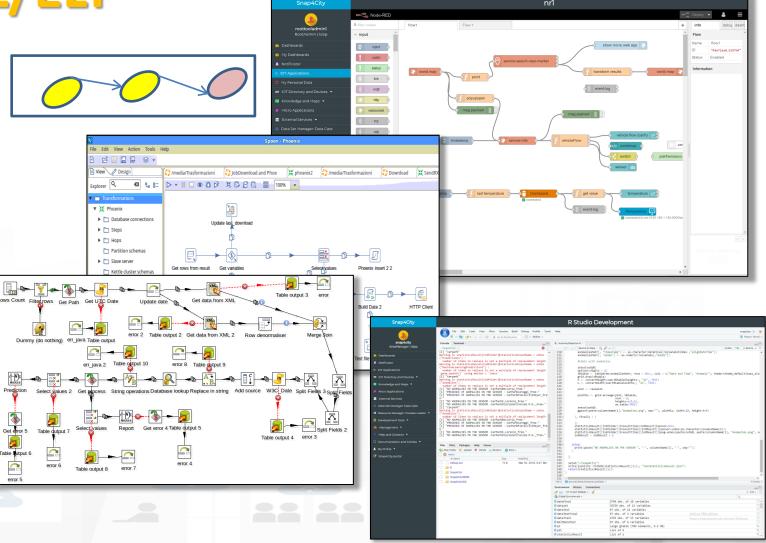






Data processing: ETL/ELT

- 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





Big Data Tools

LOD and

reasoners



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

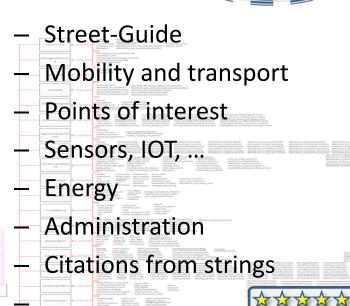
Ontology Documentation:

http://www.disit.org/6506

http://www.disit.org/6507

http://www.disit.org/5606

http://www.disit.org/6461







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/







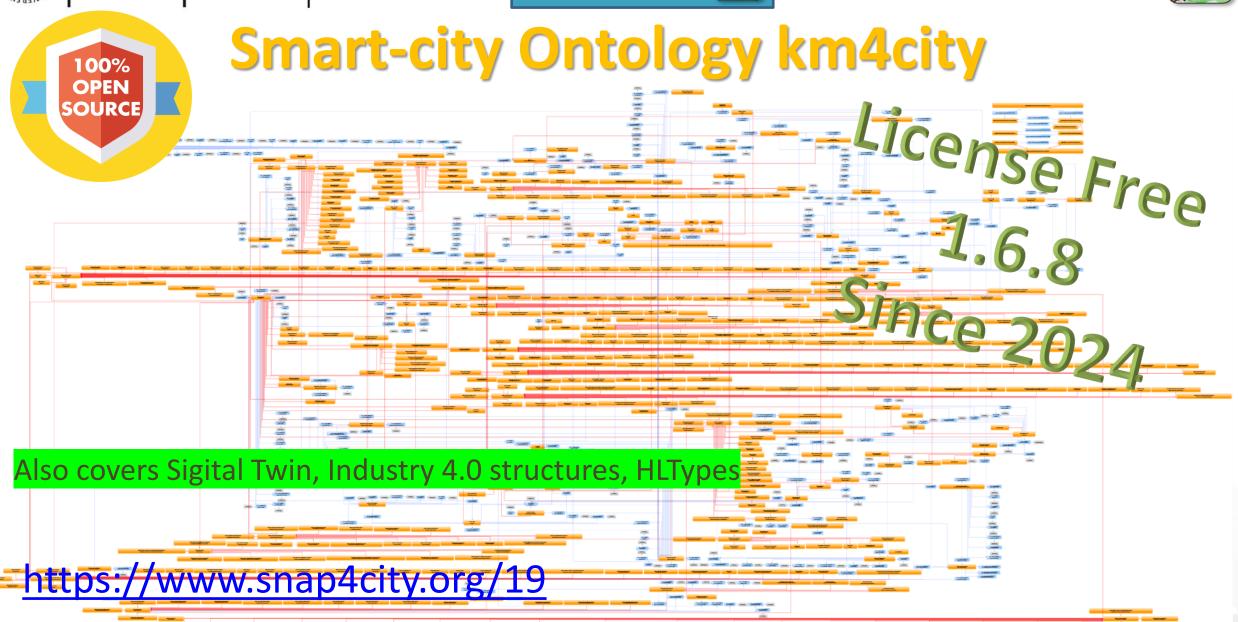
















Non structured data

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







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

Data Lake vs Data Warehouse

https://www.snap4City.org

https://www.Km4City.org











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
Transformati
on

ETL, NIFI

Indexing

SOLR, Elastic search Search and Query

Facet, cluster

Data
Analytics
Analytics
Spec
R, TF, ...
Dash

Rendering acting

User interface, Dashboard Drill down

Data Management: security, privacy, licensing, etc.







Lambda Architecture

Data
Sources
Static
Data

Data

Sources

Data

Driven

Scheduling and preproc Batch

Unified aggregation and regularizati

Big Data Indexing
Cluster
SOLR, Elastic
Searce

Search and Query Facet, cluster

Rendering acting

User interface, Dashboard Drill down

Broker,
Stream
processing

Stream

n ETL, NIFI

Knowledge base

Data

Transformatio

Analytics R, TF, ...

Data

Spec dash

Visual

Analytics

Optionally

Snap4City (C), October 2025

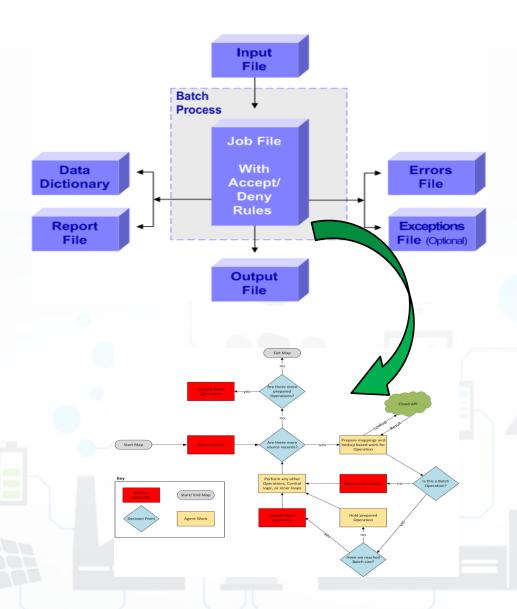
27







Batch Processing



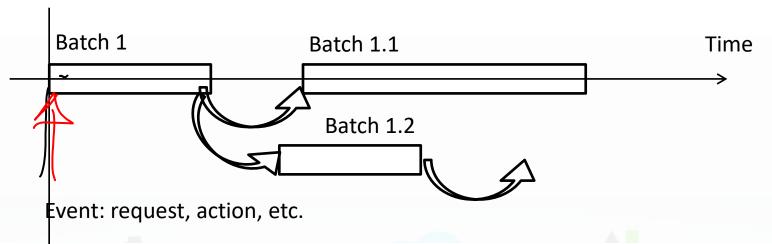
- Script language
- Smilar to workflow or flowchart
- Sequence of Commands
- Intermediate status on disk or memory
- Executed command driven:
 - On demand, sporadically
 - Periodically







aPeriodic Batch processing



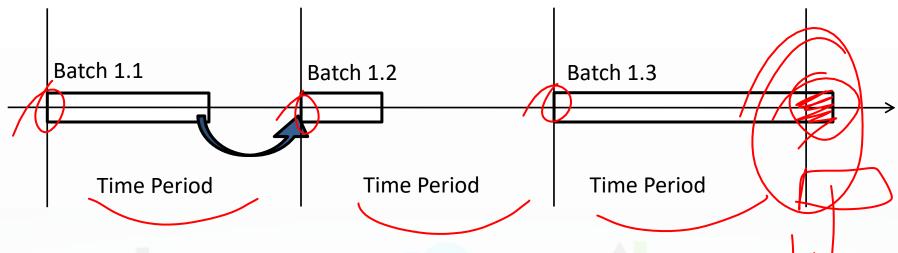
- Activated/Fired/Triggered by events, on demand, etc...
 - Synchronous with something
 - chained or not
- May fire/generate (ask to do or directly do) other jobs/batches:
 - on the same or different computers
 - Identical or different
- Activation may be asked to a third party manager
- Duration of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







Periodic Batch processing



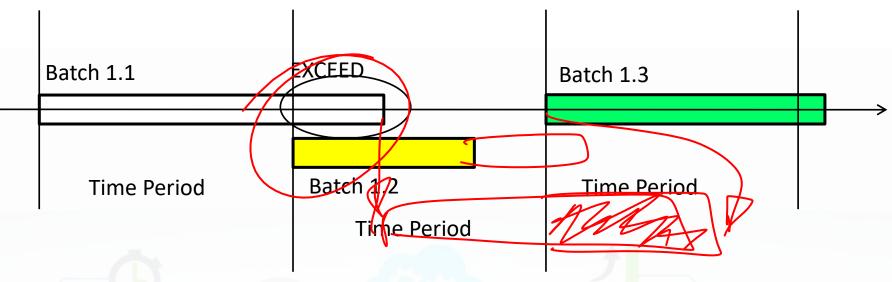
- Scheduled on periodic Firing time event (with a validity period of firing conditions from xx to yy)
 - synchronous
- Execution time duration depending on data or other...
 - Execution may exceed the Time Period
- Each single execution MAY or MAY NOT depend on the preceding one







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





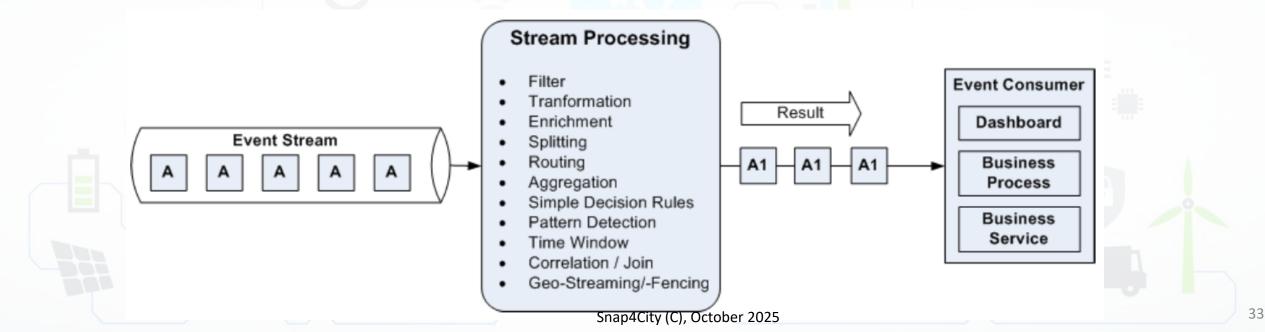
- paradigma di programmazione parallela
 - Detto anche di real time processing
- Lavora con:
 - Dati parziali e non su tutto l'insieme dei dati.
 - Per esempio: valutare il contenuto spettrale di un segnale:
 - Su tutto il segnale
 - Su una finestra temporale di 30 secondi, per ogni secondo un nuovo 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

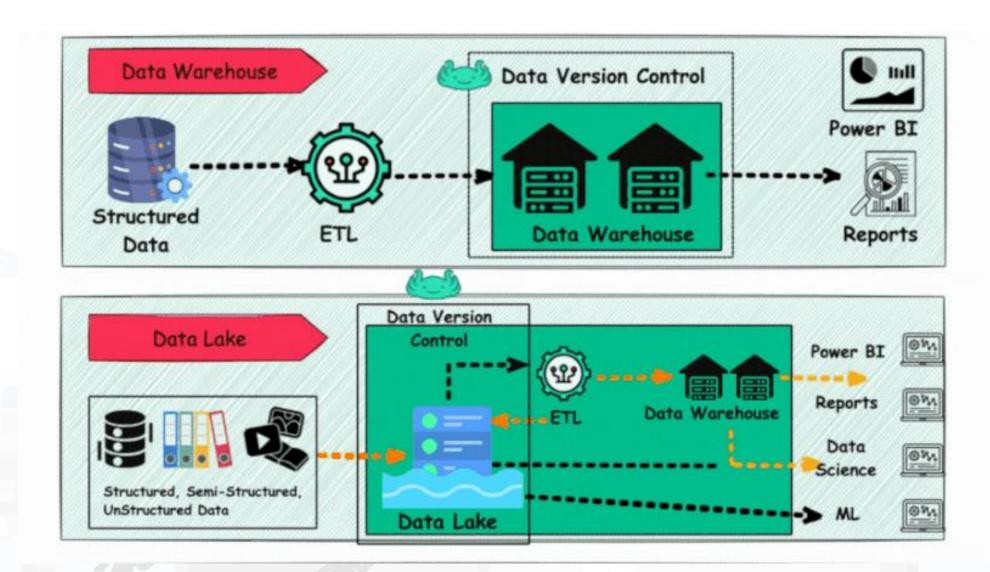
- ETL-Usage vs ELT-Usage
- DW:
 - More complex data ingestion
 - Simplify data ingestion for sporadically used data
 - Faster date usage unforeseen patterns/combinations
- DL:
 - Faster data ingestion
 - More complex data rendering since all combination are unplanned
 - Prepare data rendering for well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



















Parameters	Data Lake (Data Warehouse
Storage	In the data lake, all data is kept irrespective of the source and its structure. Data is kept in its raw form. It is only transformed when it is ready to be used.	A data warehouse will consist of data that is extracted from transactional systems or data which consists of quantitative metrics with their attributes. The data is cleaned and transformed
History	Big data technologies used in data lakes is relatively new.	Data warehouse concept, unlike big data, had been used for decades.
Data Capturing	Captures all kinds of data and structures, semistructured and unstructured in their original form from source systems.	Captures structured information and organizes them in schemas as defined for data warehouse purposes
Data Timeline	can retain all data. This includes not only the data that is in use but also data that it might use in the future. Also, data is kept for all time, to go back in time and do an analysis.	In the data warehouse development process, significant time is spent on analyzing various data sources.
Users	ideal for the users who indulge in deep analysis. Such users include data scientists who need advanced analytical tools with capabilities such as predictive modeling and statistical analysis.	The data warehouse is ideal for operational users because of being well structured, easy to use and understand.
Storage Costs	Data storing in big data technologies are relatively inexpensive then storing data in a data warehouse.	Storing data in Data warehouse is costlier and time-consuming.

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







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.
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.
	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.







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











Data
Sources
Static
Data

Data

Sources

Data

Driven

Scheduling and preproc

Broker, Stream processing

Stream

Batch

Unified aggregation and regularizati on

Big Data Indexing
Cluster SOLR,
Elastic
HDFS, noSQL search

Data
Transformati
on
ETL, NIFI

Analytics R, TF, ...

Data

Facet, cluster

Search and

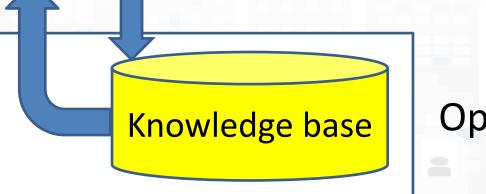
Query

Visual Analytics

Spec dash

Rendering acting

User interface, Dashboard Drill down



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











Batch

Data Sources Static Data

Schedulin g and preproc

Big Data Cluster With some raw index noSQL Storage

Search and Query

Data **Transfor** mation

Data **Analytics**

Tempora

ry data

storage

Storage

Storage

Storage

Visual **Analytics** Rendering acting

User interface, Dashboard

Sources Data Driven

Data

Broker, Stream processing

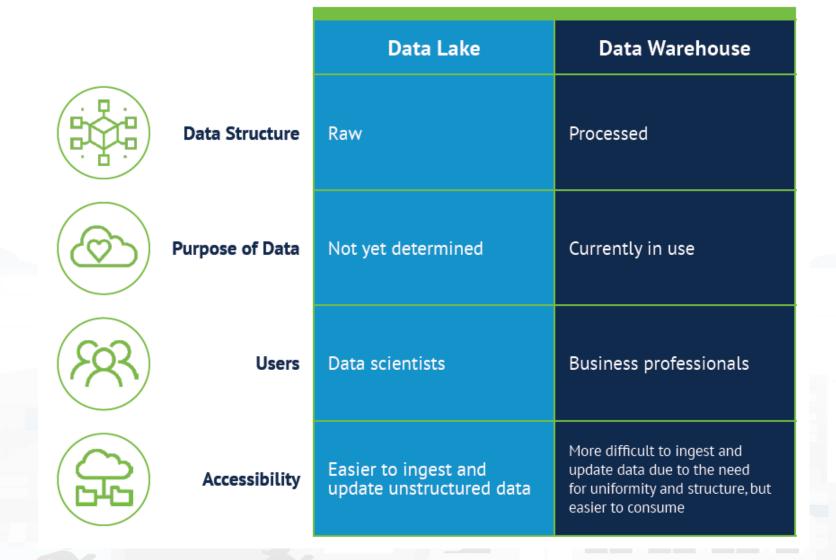
Stream











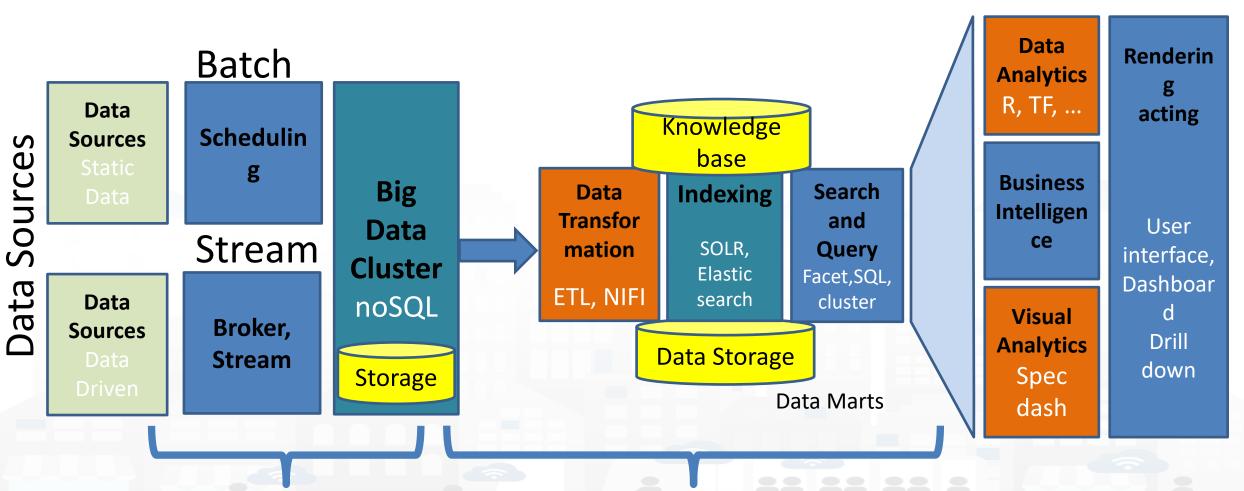








Combined Solutions



Data Lake

Data WareHouse



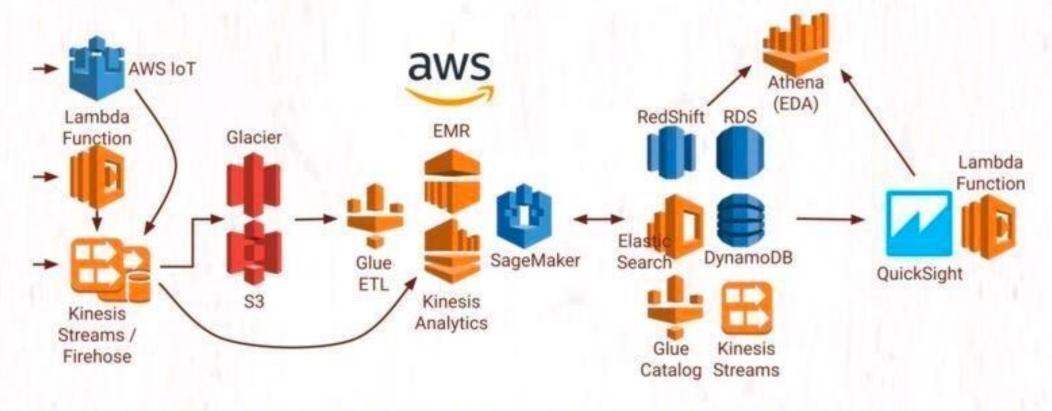






Big Data Pipelines on AWS, Microsoft Azure, and GCP

scgupta.link/big-data-pipeline



Ingestion

Data Lake

Preparation & Computation

Data Warehouse

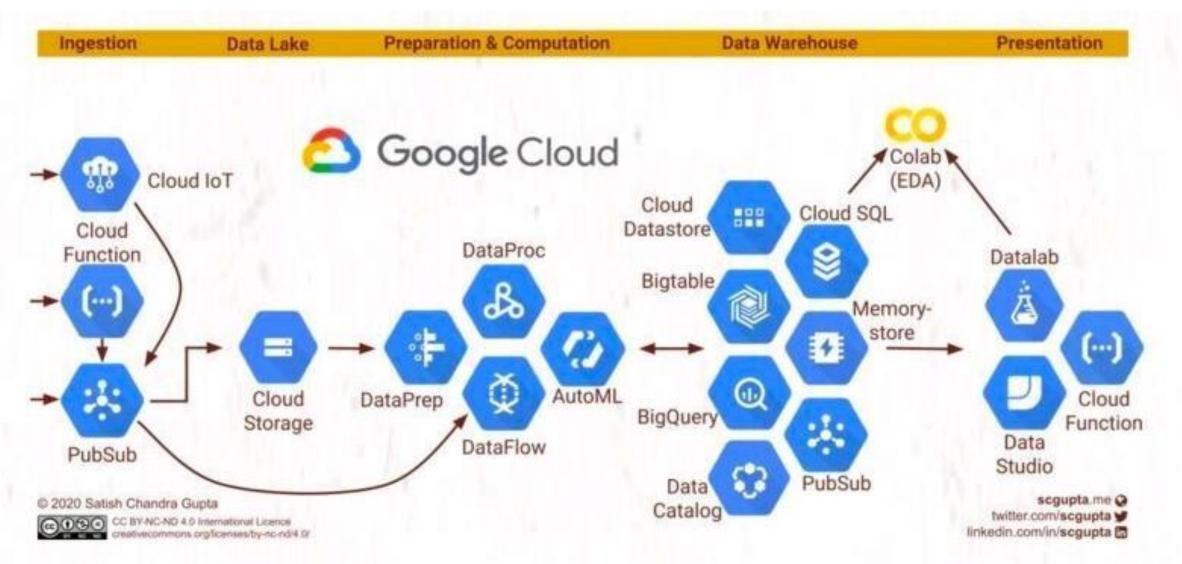
Presentation









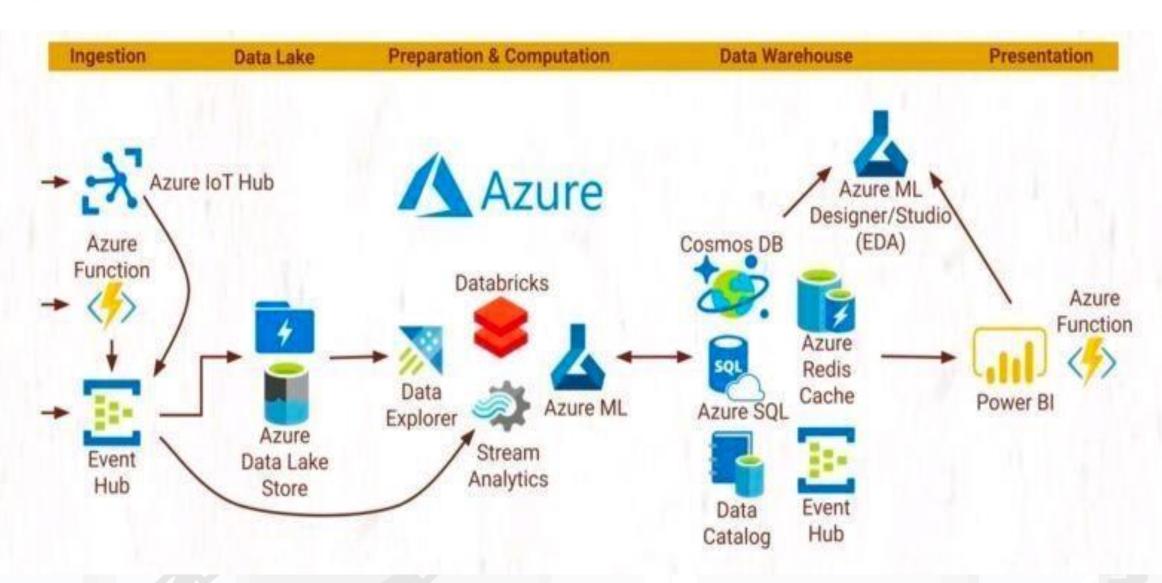






DINFO





CLOUD COMPARISON

AWS VS. AZURE VS. GOOGLE



@simonholdorf







Avalaible Regions

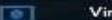
AWS Regions and Zones

Azure Regions

Google Compute Regions & Zones

Compute Services





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 Dynams DE (C), October 2025

Azure DocumentDB



Cloud Datastore

CLOUD COMPARISON

AWS VS. AZURE VS. GOOGLE



@simonholdorf







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

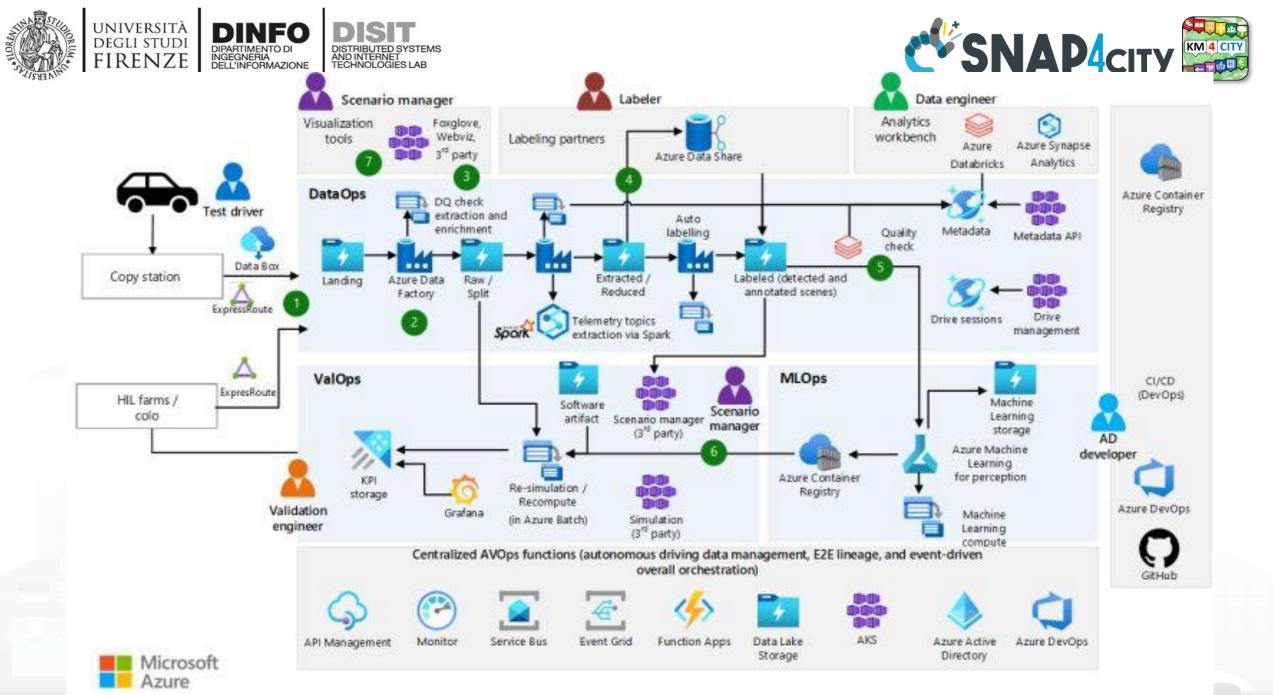


Amazon Simple Notification Service (SNS)



Azure Notification Hub

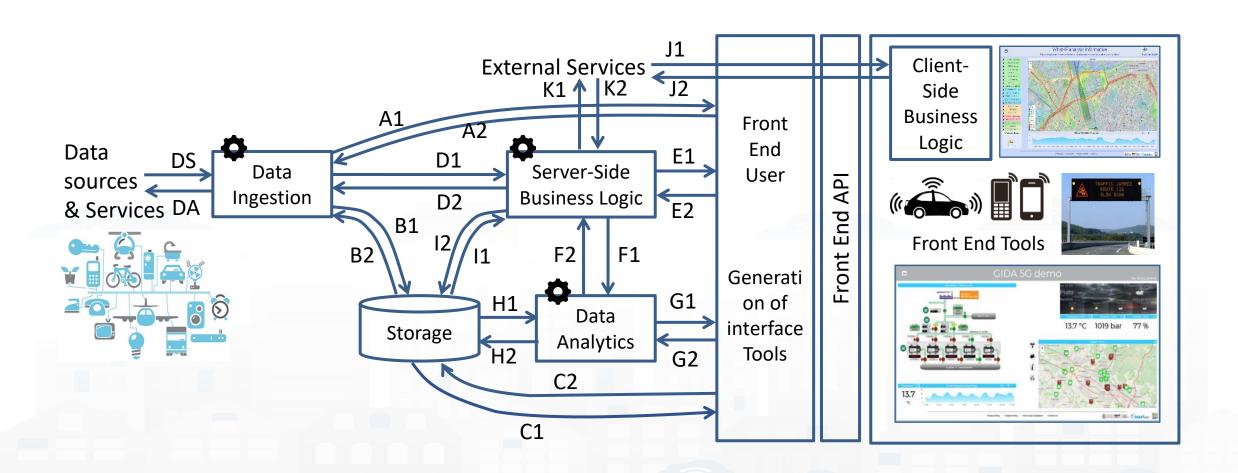
None

















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

IoT Architectures

https://www.snap4City.org

https://www.Km4City.org













10T Solutions





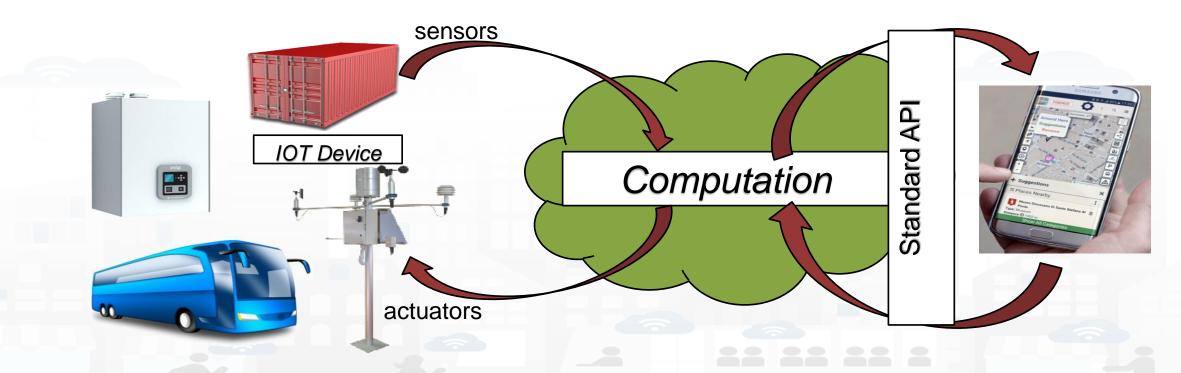








- IOT Main Concept The implementation of smart services may implies the:
 - acquisition of data from the field
 - computation and imposition of actions/values
 - Save of historical values, computer data analytics, etc.





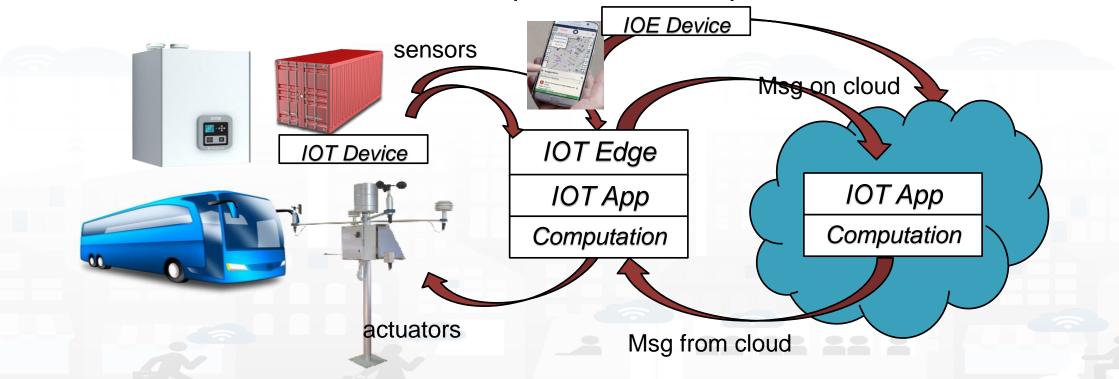








- The implementation of smart services may implies the:
 - acquisition of data from the field
 - computation and imposition of actions/values
 - Save of historical values, computer data analytics, etc.



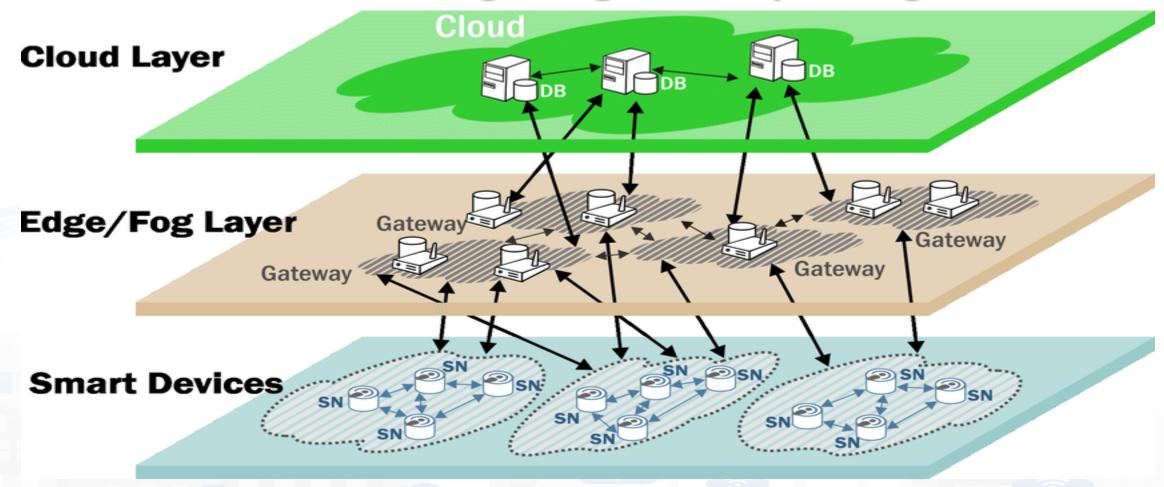


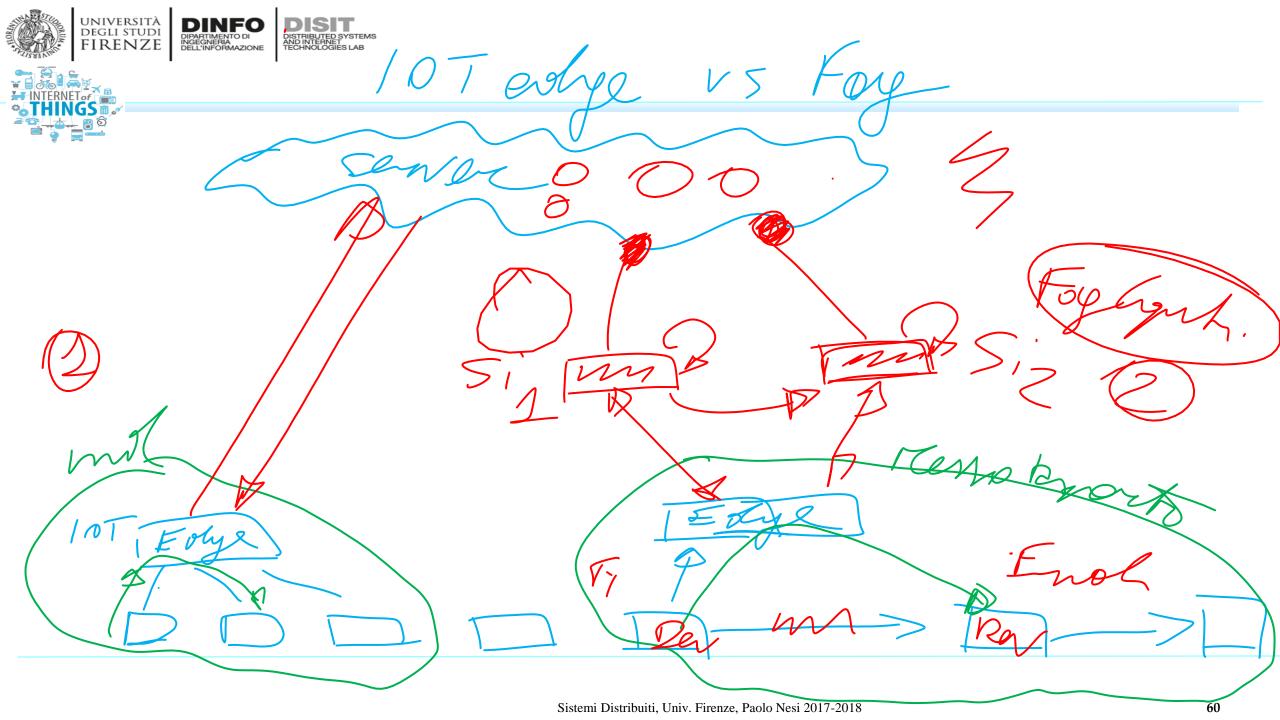






Cloud vs Fog/Edge Computing





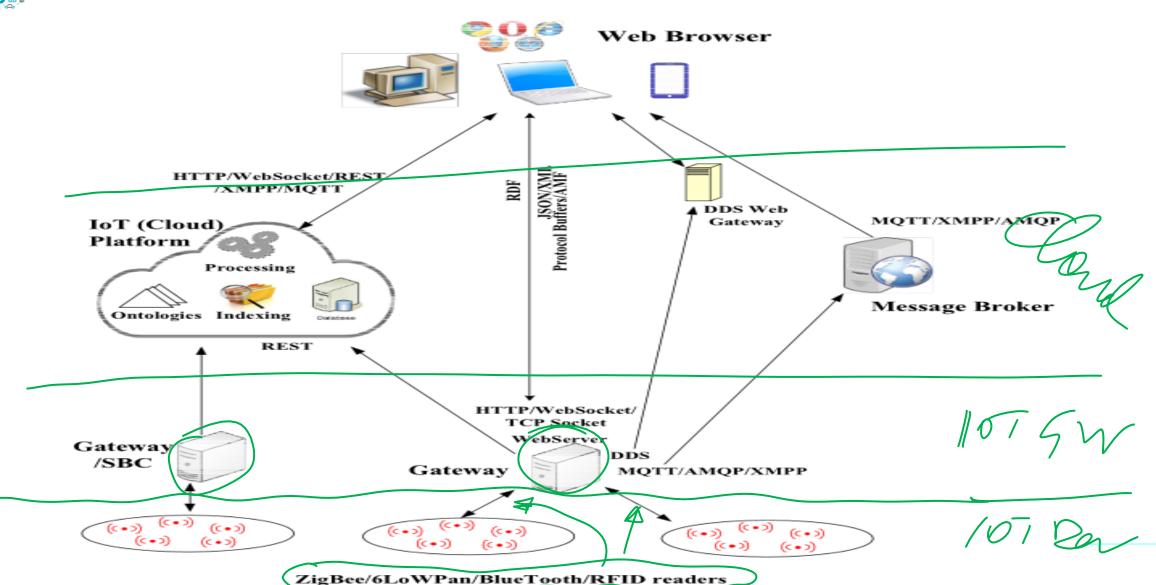








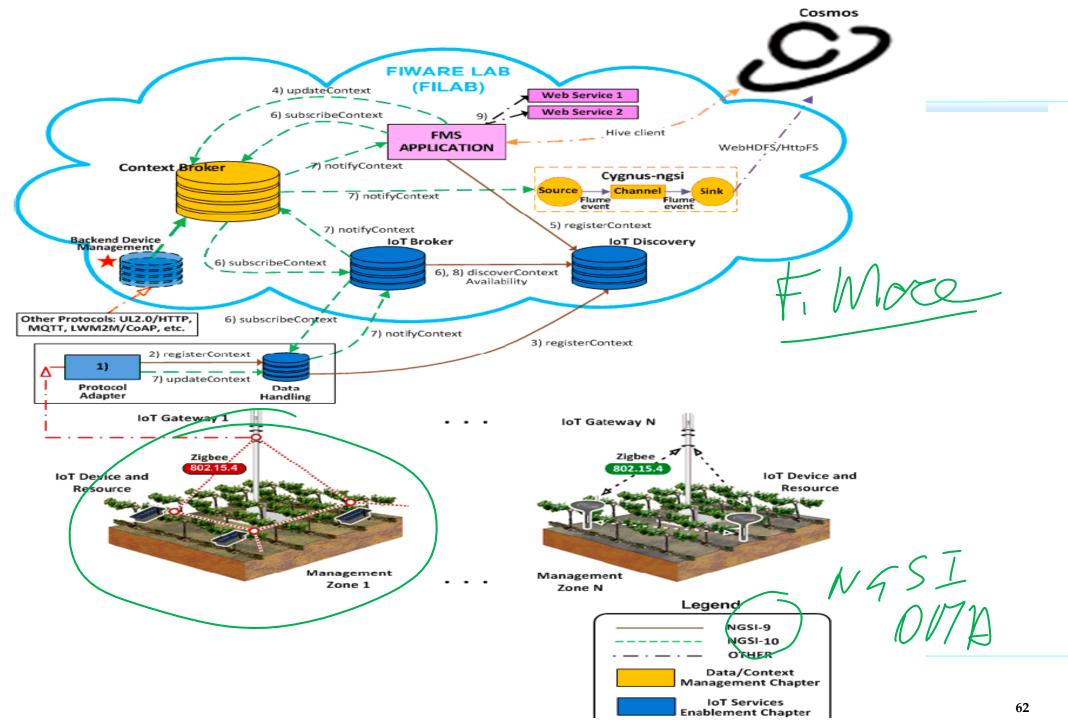
Edge Computing, Fog Computing



Sistemi Distribuiti, Univ. Firenze, Paolo Nesi 2017-2018



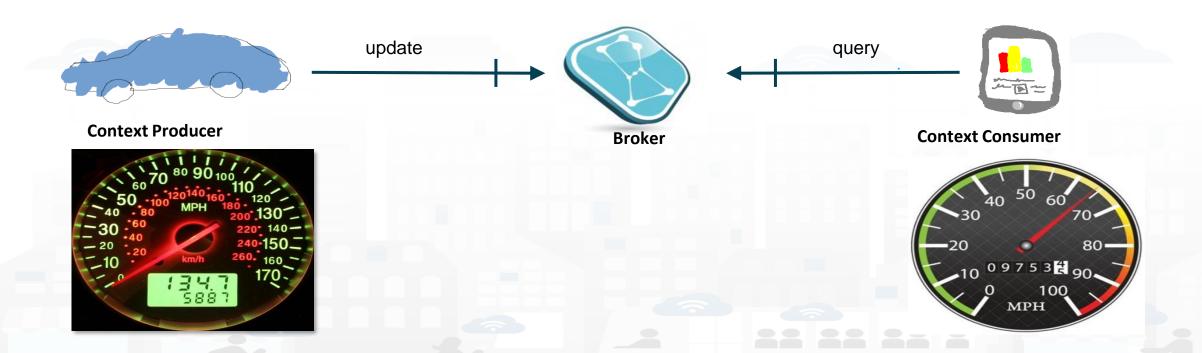








- Broker operations: create & political data contact the contact of th
 - Context Producers publish data/context elements by invoking the update operations on a Context Broker.
 - Context Consumers can retrieve data/context elements by invoking the query operations on a Context Broker









IOT Broker

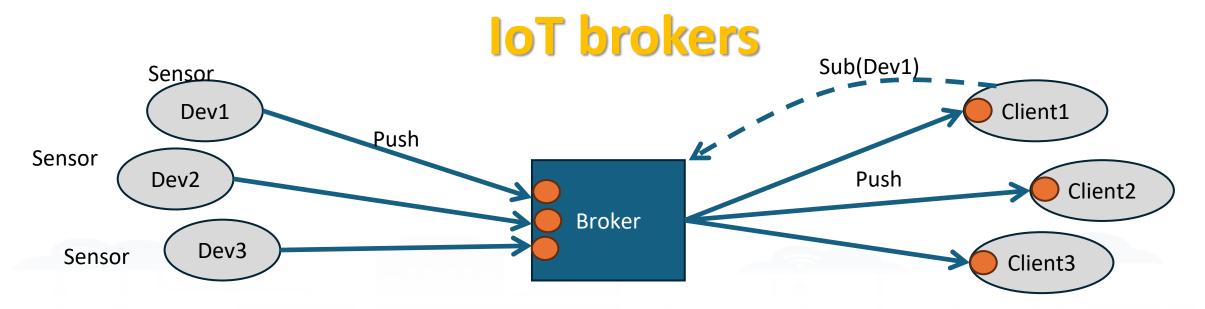


- Broker operations: create & pull data
 - Context Producers publish data/context elements by invoking the update operations on a Context Broker.

Context Consumers can retrieve data/context elements by invoking the guery operations or a **Context Broker** query **Context Producer** Broker **Context Consumer** 10 0 9 7 5 3 4 00







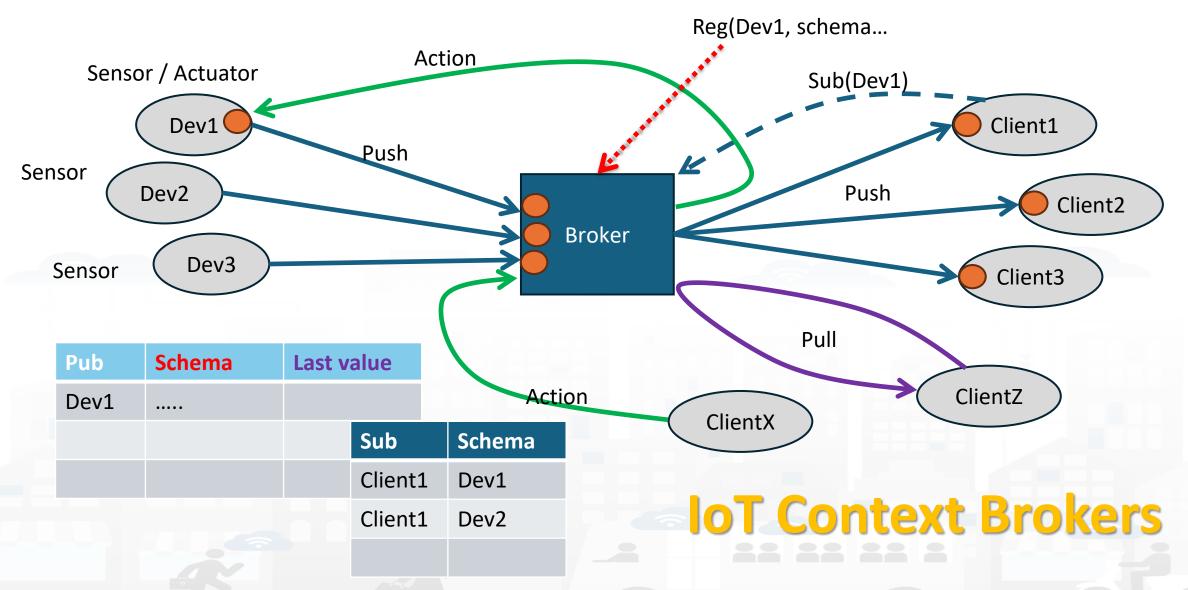
Pub

Dev1

Sub	Schema
Client1	Dev1
Client1	Dev2



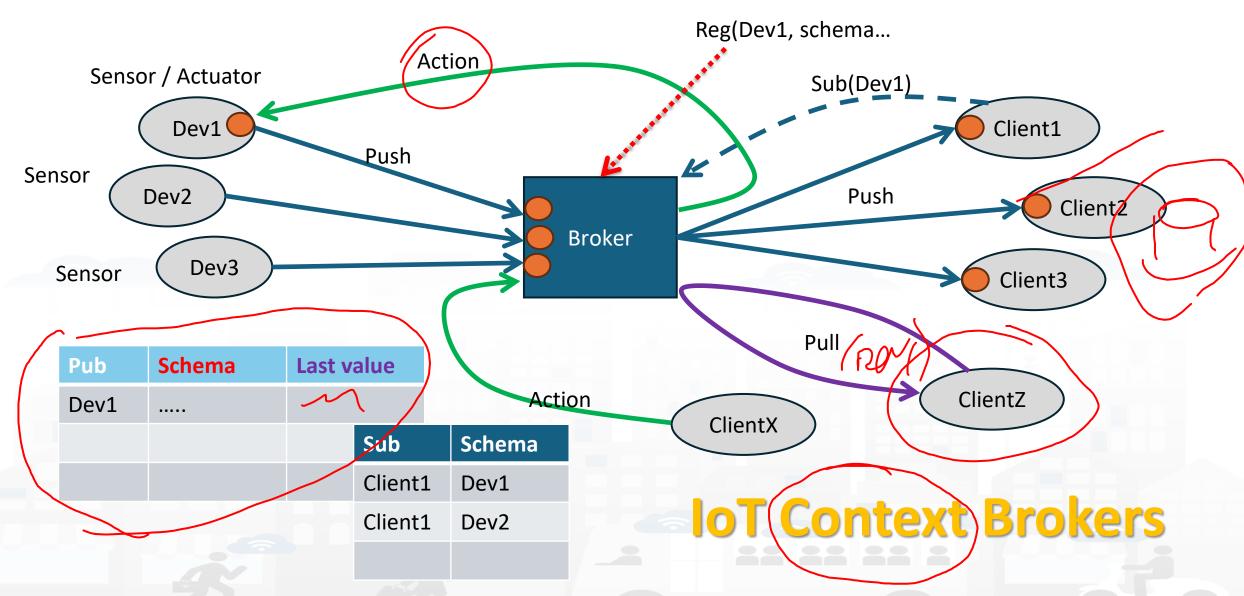






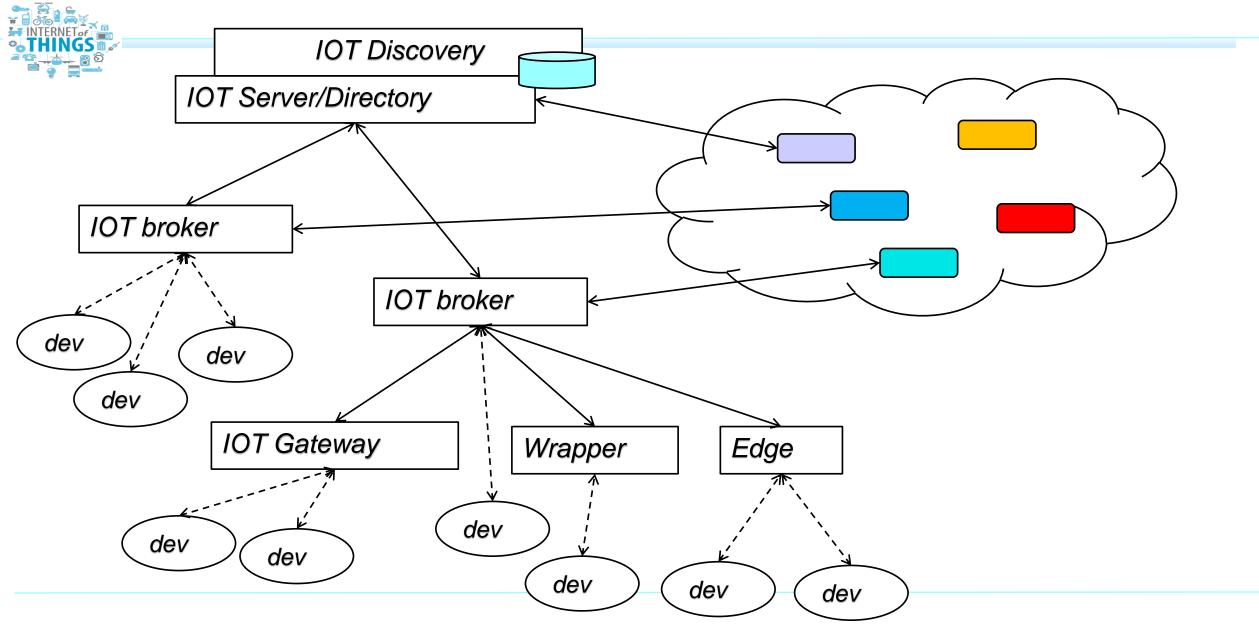


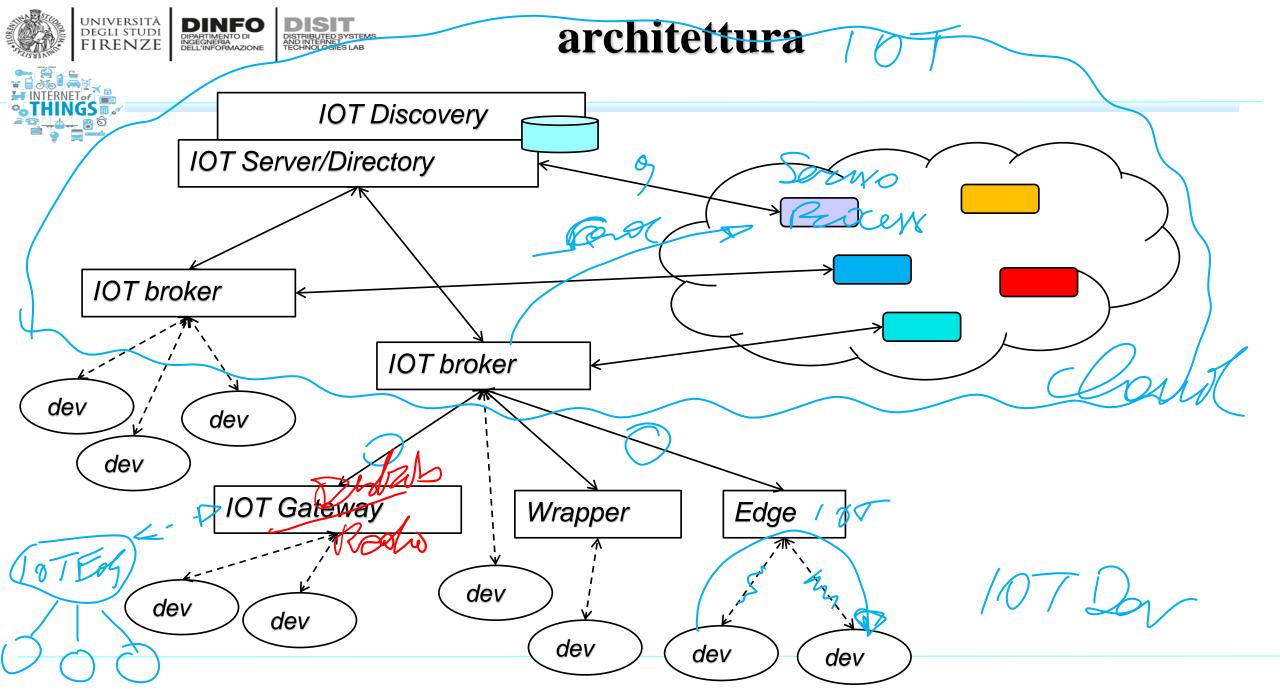






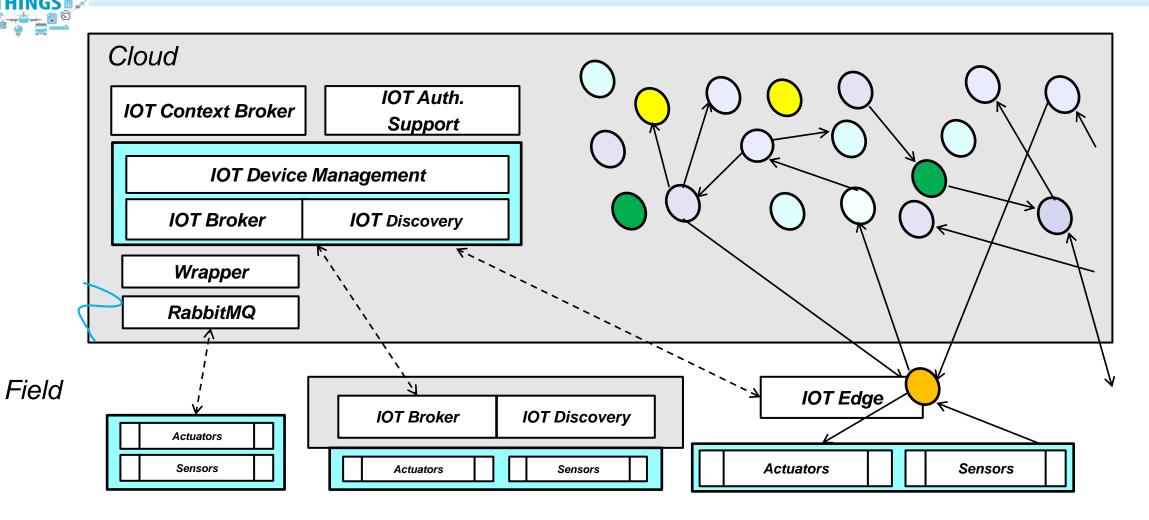
architettura

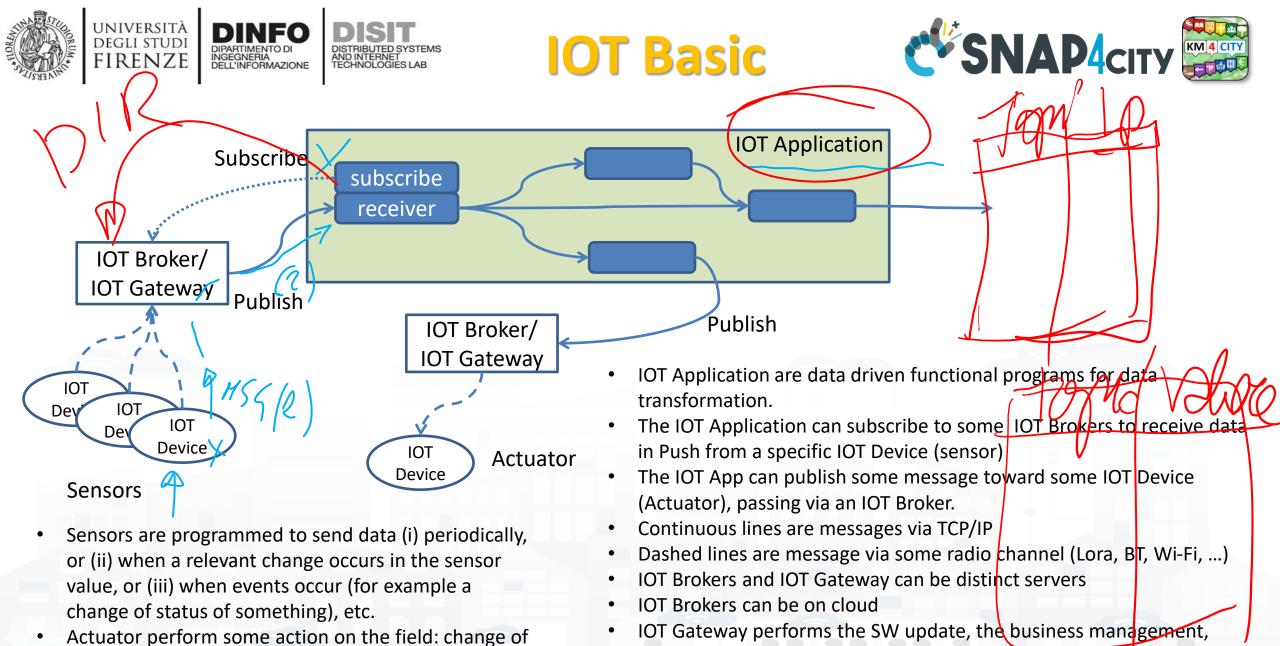






Conceptual architecture





status, reset, turn on something, change setting

value, etc.

access in Push and Pull





IOT Broker

IOT Broker

IOT

Device

Device

Device

IOT Gateway

IOT

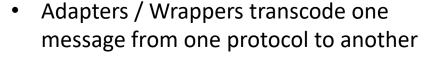
IOT

Definitions



IOT Application

IOT Brokers can be connected each other



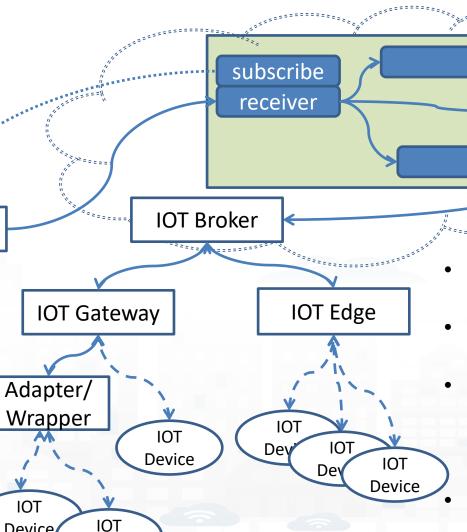
IOT Gateway

IOT

Device

IOT

Dev



- 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

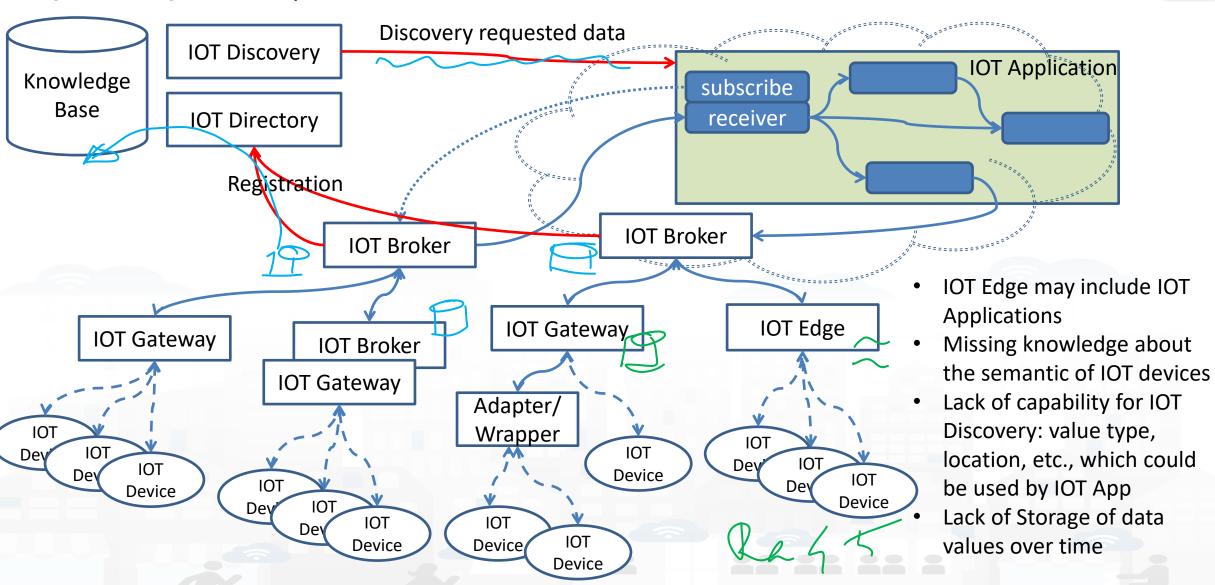






Definitions





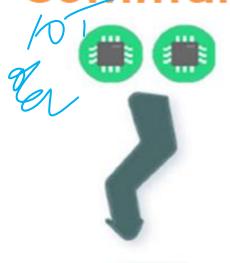








Communication Patterns





Discover register and "thrust" new devices on the network

Registration



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

Push

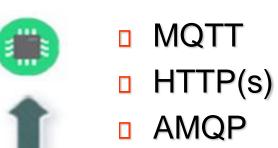


Inquiries
Requests from devices looking to gather required information or asking to initiate activities



perform specific activities

Bulk action



- COAP
- NGSI
- OneM2M
- WebSocket

S

- Etc.



Notifications

Information flows

device or a group

status changes in

from other

systems to a

for conveying

the world







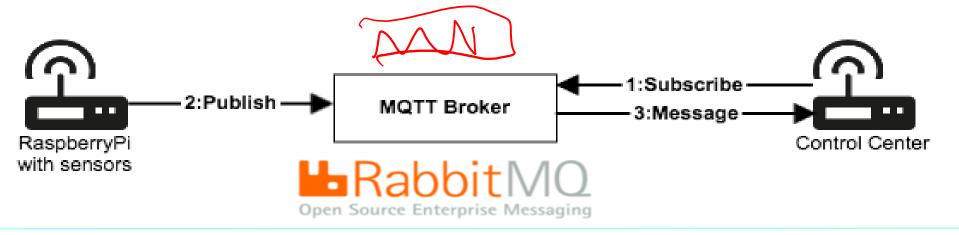
Note on Communication patterns

- Not all Communication Patterns are supported by all Protocols
- Protocols implement Patterns, + formats, + sequences, etc.
- They are referred at level of communications
 - IOT Device \leftarrow → IOT Gateway \leftarrow →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

CONTROL CONTRO	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





DINFO DIST DISTED SYSTEMS AND INTERIES LAB OF STACK PROTOCOLS

Session		MQTT, SMQTT, CoRE, DDS, AMQP, XMPP, CoAP,	
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,	

Security Management TCG, **IEEE 1905**, Oath 2.0, **IEEE 1451**, SMACK, SASL, ISASecure, ace, DTLS, Dice, ...

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



Comparison high level IOT protocols

Protocols	UDP/TCP	Architecture	Security and GoS	Header Size (bytes)	Max Length(bytes)
MQTT	TCP /	Pub/Sub	Both	2	5 750W
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	Qub/848	POS	7	

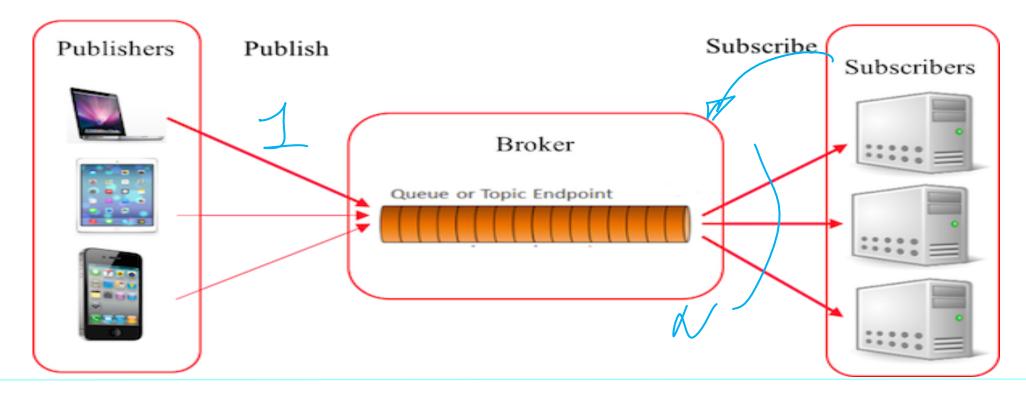






MQTT: Message Queue Telemetry Transport

- 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)

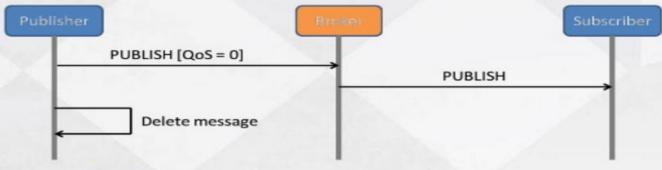




MQTT QoS

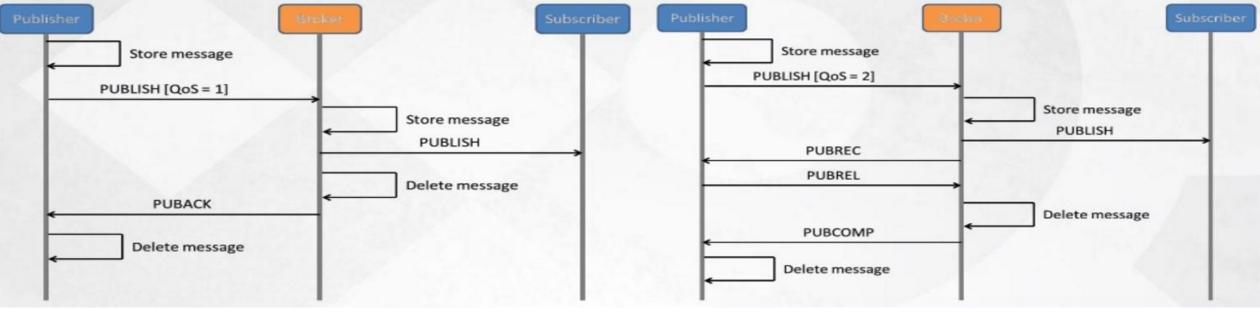


QoS 0 : At most once (fire and forget)



QoS 1: At least once

QoS 2: Exactly once

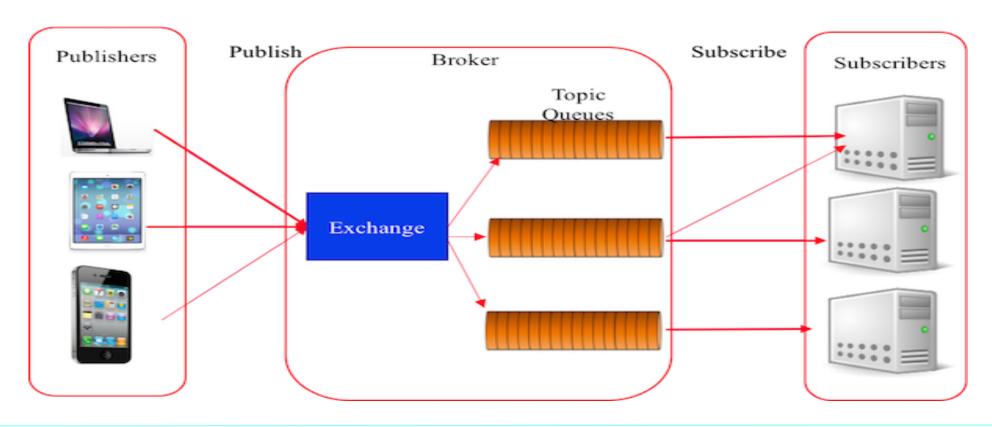






AMQP Advanced Message Queuing Protocol

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

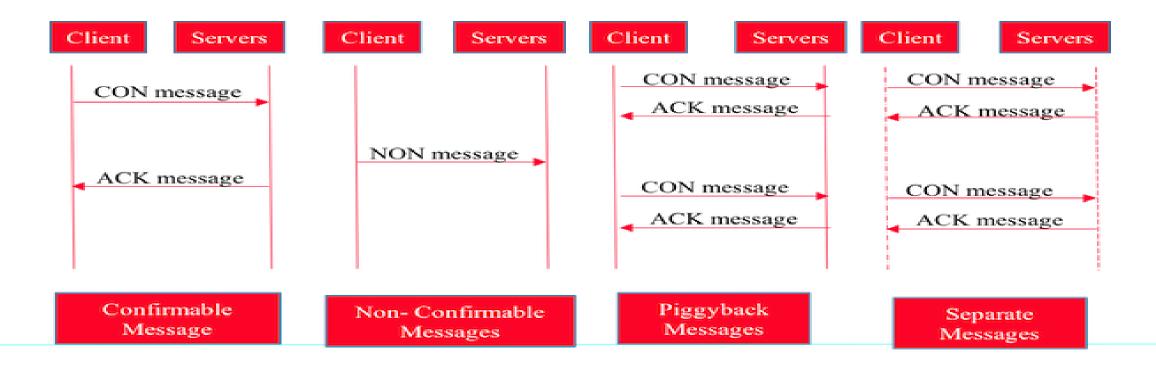






CoAP: Constrained Application Protocol

- 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





pisit per comparison of lowlevel IOT prot.

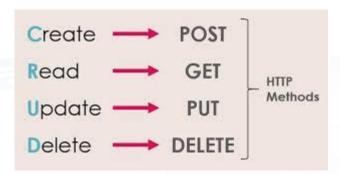
Protocolli	Standard	Frequenza	Range	Data Rates
IoT Bluetooth	Bluetooth 4.2	2.4GHz (ISM)	50-150m (Smart/BLE)	1Mbps (\$mart/BLE)
ZigBee	ZigBee 3.0 based on IEEE802.15.4		10-100m	250kbps
6LoWPAN		(adapted and used over a variety of other networking media including Bluetooth Smart (2.4GHz) or ZigBee or low-power 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	/- /-	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

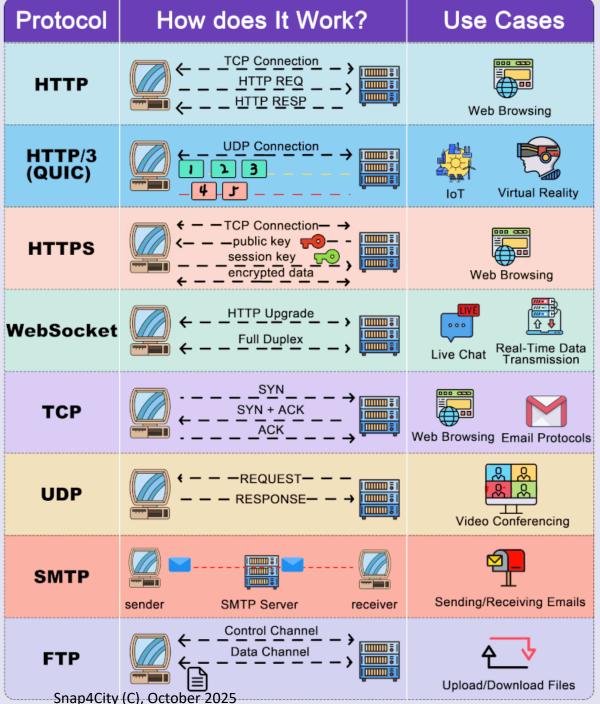






Main protocols



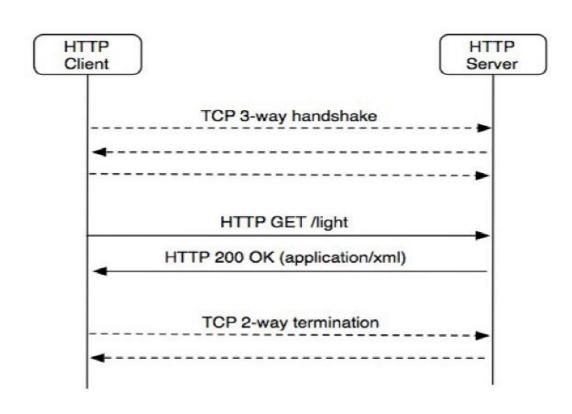


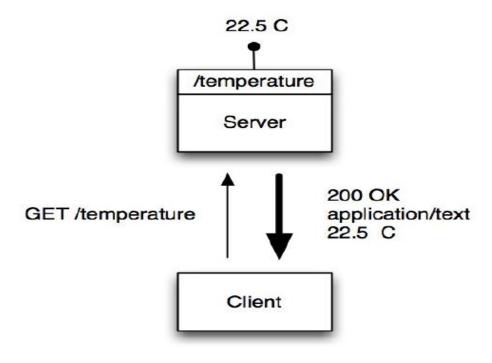






HTTP GET













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 Request Methods





Retrieves data or resources from a specified URL. It is used to retrieve information without modifying it.





Submits data or creates a new resource on the server. It is used to send data to be processed by the server, often resulting in the creation of a new resource.





Updates an existing resource with new data. It replaces the entire resource with the new representation provided.





Deletes a specified resource on the server.





Partially updates an existing resource. It is used to apply modifications to a resource, specifying only the changes that need to be made.





Retrieves only the headers of a response. It is used to check the status or headers of a resource without fetching the entire content.





Retrieves the allowed methods and other information about a resource.





Echoes back the received request to the client. It is mainly used for diagnostic purposes.





Establishes a tunnel connection to a remote server, typically through a proxy server.

www.automateNow.io







	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



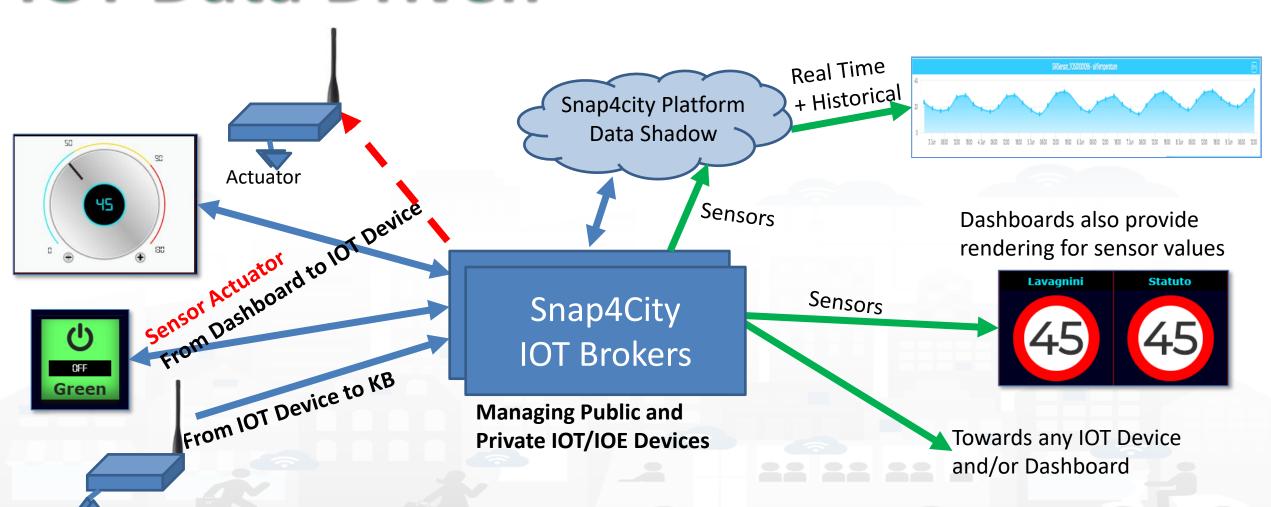
Sensors







IOT Data Driven



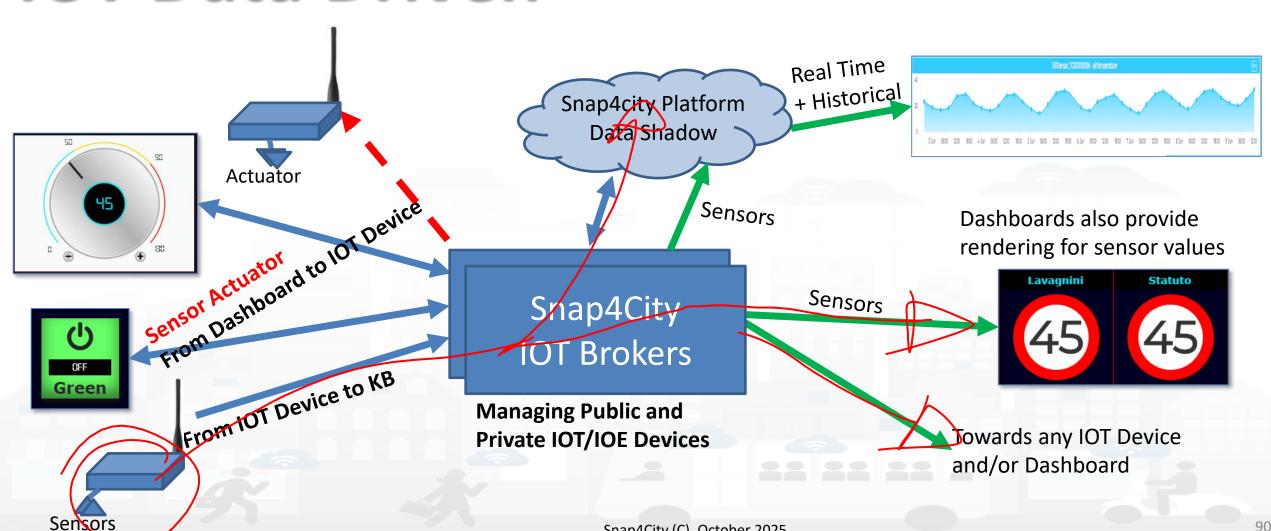








IOT Data Driven



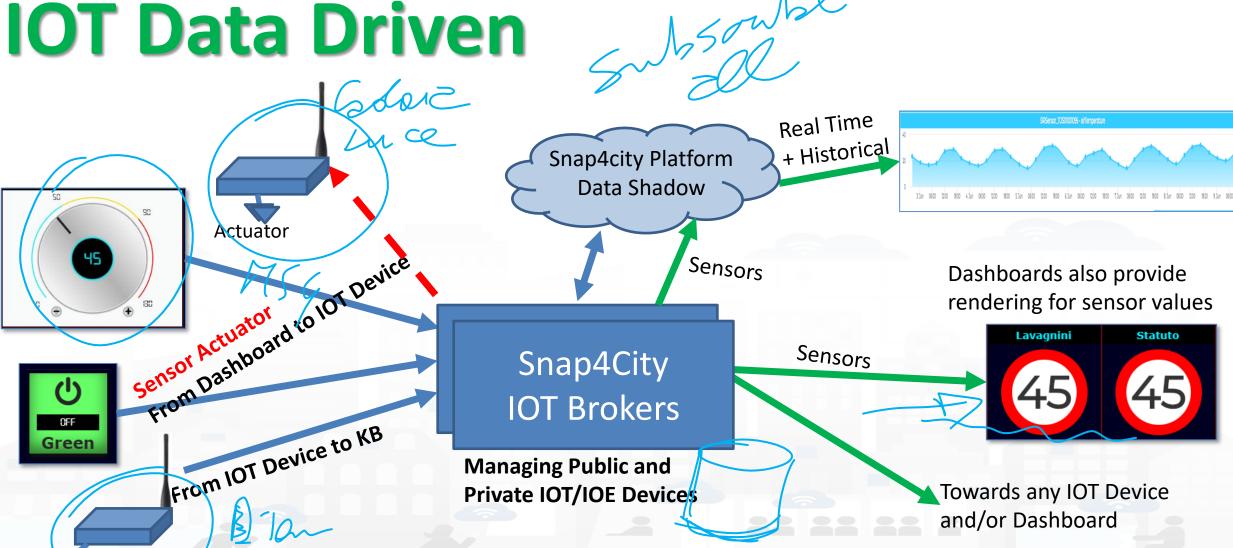


Sensors



















IOT Architectures Comparison



Market Solutions



	OT Discovery Abstraction	A (thentication, Authorization,	Security end-2-end, secure on OT and Dashboards	Open HW and Open SW	ntegrated Community management	Jata Types: IOT Devices, IOT App, Dashboard, Data	Data Type: Publish/share, Ф Delegation, Consent and change	Data Type: Download and O Delete	Auditing on Data Type Access	Open Source end-to-en	Stalability 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 IO1	
Snap4City	Υ	G Y	Υ	Υ	Υ	γ	۷	V	V	V	V	V	V	Υ	γ	Υ	Υ	Υ	Υ	
KAA [53]	Y	Υ	Υ	Υ	Υ	Y	N	Y	Υ	Y	Y	N	Y	N	(Y)	N	N	Y	Y	
Thingsboard [55]	Y	Υ	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	Υ	N	N	N	Υ	Υ	N	N	N	Υ	N	N	N	Υ	
IOT IGNITE [57]	N	Υ	N	Y	N	Υ	N	Υ	Υ	Υ	Υ	Υ	N	N	N	N	N	Υ	MQTT	
FIWARE [47]	N	Υ	N	Υ	N	N	N	Υ	N	Υ	(Y)	(N)	Υ	N	Υ	N	N	Υ	Y	
ARM mbed IoT [48]	Υ	Υ	Υ	Υ	Υ	N	(N)	N	Υ	Υ	Υ	N	N	N	Υ	N	N	Υ	Limited	
Airvantage [51]	Υ	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ	Υ	N	N	N	N	N	N	Υ	MQTT, HTTP	
AWS [43]	Υ	Υ	Υ	Υ	N	Υ	(N)	Υ	Υ	N	Υ	N	N	N	Υ	Υ	(Y)	Υ	Limited	
Azure IOT [44]	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	N	Υ	N	N	N	Υ	Υ	(Y)	Υ	Limited	
PTC ThingWorkx [59]	N	Υ	Υ	Υ	Υ	Υ	N	N	Υ	N	Υ	Υ	N	N	Υ	N	N	Υ	Υ	
Bosch IoT Suite [58]	Υ	Υ	Υ	Υ	Υ	(Y)	(N)	Υ	Υ	N	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ	
CISCO Jasper [55]	Υ	Υ	Υ	Υ	N	(Y)	(N)	N	Υ	N	Υ	N	N	N	N		(Y)	Υ	N	
Siemens MindSphere [60]	Y	Y	Υ	(Y)	N	Υ	(N)	Υ	Υ	N	Υ	Υ	N	N	Υ	N	Υ	Υ	Y	
Carriots [54]	Υ	Υ	Υ	(Y)	N	Υ	N	N	Υ	N	Υ	N	N	N		N	N	Υ	MQTT	
Google IOT [45]	Υ	Υ	Υ	Υ	Υ	Υ	N	Υ	Υ	N	Υ	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP	
Homekit Apple [50]	Y	Υ	Υ	Υ	N	Υ	N	N	Υ	N	(Y)	N	N	N	N	Υ	N	Υ	Limited	
Smarthing Samsung [52]	Υ	Υ	Υ	Υ	Υ	Υ	(Y)	Υ	Υ	N	(Y)	N	N	N	N	N	N	Υ	Limited	

Snap4City	Market S	ol		Q	ns					" Bus			OTAPP	*	3 of				S	NAP4city
Snap4City		OT Discovery Abstraction		Security end-2-end, secure on OT and Dashboards	Open HW and Open SW	ntegrated Community nanagement	Types: IOT Dashboard	Data Type: Publish/share, Delegation, Consent and change	Data Type: Download and Delete	on Data Type	Open Source end-to-end	Scalability IOT	Visual Programming end-to-end applications	art City	Multi Domain Semantic	dard based Modules Open Devices	Resource Sharing	Data Analytics integrated	H24/7,	Multi-protocol on IOT
KAA [53]							G	G	G											_
Thingsboard [55]			Υ	Υ	Υ	-	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ		Y
IOT eclipse.org [56]				Υ	Υ	Υ	Υ	N	Υ	Υ	Υ	Υ	N	Υ	N	(Y)	N	N	Υ	
IOT IGNITE [57]		Υ	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ	Υ	N	N	N	N	N	N	Υ	MQTT,coap, http
FIWARE [47] N Y N Y N N Y N Y N Y N Y N Y N Y N Y N Y N Y N Y N N Y N Y N N Y N N Y N N N Y N N N Y N N N N N N N N N N N N N N Y N <th< td=""><td></td><td>N</td><td>N</td><td>N</td><td>(Y)</td><td>N</td><td>Υ</td><td>N</td><td>N</td><td>N</td><td>Υ</td><td>Υ</td><td>N</td><td>N</td><td>N</td><td>Υ</td><td>N</td><td>N</td><td>N</td><td>\mathcal{O}</td></th<>		N	N	N	(Y)	N	Υ	N	N	N	Υ	Υ	N	N	N	Υ	N	N	N	\mathcal{O}
ARM mbed IoT [48] Y	IOT IGNITE [57]	N	Υ	N	Υ	N	Υ	N	Υ	Υ	Υ	Υ	Υ	N	N	N	N	N	Υ	MQTT
Airvantage [51] Y	FIWARE [47]	N	Υ	N	Υ	N	N	N	Υ	N	Υ	(Y)	(N)	Υ	N	Υ	N	N	Υ	<u>(Y)</u>
AWS [43] Y Y Y Y Y Y Y Y Y Y Y N Y N Y N N	ARM mbed IoT [48]	Υ	Υ	Υ	Υ	Υ	N	(N)	N	Υ	Υ	Υ	N	N	N	Υ	N	N	Υ	Limited
Azure IOT [44] Y	Airvantage [51]	<u> </u>	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ	Υ	N	N	Ņ	N	N	N	Υ	MQTT, HTTP
PTC ThingWorkx [59] N Y Y Y Y Y Y N N Y Y N N Y Y N Y Y N Y Y N Y Y N Y Y N Y N Y N Y N N N Y N N Y N N N N N N N	AWS [43]	Υ	Υ	Υ	Υ	N	Υ	(N)	Ŷ	Υ	Ν	Υ	Ν	N	N	Υ	Υ	(Y)	Υ	Limited
Bosch IoT Suite [58] Y N Y N N N N N N Y N N N N N N N Y N	Azure IOT [44]	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Ν	Υ	N	N	N	Υ	Υ	(Y)	Υ	Limited
CISCO Jasper [55] Y Y Y Y Y N (Y) (N) N Y N N N N N (Y) Y N Siemens MindSphere [60] Y N Y N N N N N N N Y Y Y Y Y Y Y N<	PTC ThingWorkx [59]	N	Υ	Υ	Υ	Υ	Υ	N	N	Υ	Ν	Υ	Υ	N	N	Υ	N	N	Υ	Υ
Siemens MindSphere [60] Y N Y N Y N	Bosch IoT Suite [58]	Υ	Υ	Υ	Υ	Υ	(Y)	(N)	Υ	Υ	Ν	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ
[60] Y Y Y (Y) N Y (N) Y Y N Y N N Y N Y Y Y Y Y Y Y Y Y Y Y	CISCO Jasper [55]	Υ	Υ	Υ	Υ	N	(Y)	(N)	N	Υ	Ν	Υ	N	N	N	Ν		(Y)	Υ	N
Google IOT [45] Y Y Y Y Y Y Y N Y N N N N N (Y) MQTT, HTTP Homekit Apple [50] Y Y Y N N Y N N N N N N Y N Y Limited		Υ	Y	Υ	(Y)	N	Y	(N)	Y	Y	N	Y	Υ	N	N	Υ	N	Υ	Υ	Υ
Homekit Apple [50] Y Y Y N Y N N N N N N N N N Y Limited	Carriots [54]	Υ	Υ	Υ	(Y)	N	Υ	N	N	Υ	Ν	Υ	N	N	N		N	N	Υ	MQTT
	Google IOT [45]	Υ	Υ	Υ	Υ	Υ	Υ	N	Υ	Υ	Ν	Υ	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP
	Homekit Apple [50]	Υ	Υ	Υ	Υ	N	Υ	N	N	Υ	Ν	(Y)	N	N	N	N	Υ	N	Υ	Limited
ornarining cambaing [oz]	Smarthing Samsung [52]	Υ	Υ	Υ	Υ	Υ	Υ	(Y)	Υ	Υ	Ν	(Y)	N	N	N	N	N	N	Υ	Limited

						Azuı	e IoT		AWS	G	oogle Io	Т	
		Data di	rilascio	(Out of	beta)	Febbra	nio 2016	Dicer	nbre 201	5 Feb	braio 20	018	
	-	Quota	di merca	ato		31.:	21%	5	1.82%		18.79%		
70%	62.61%												2016
60%	- "	54.10%											2017 2018
50%	-												
40%	-		34.95%										
30%	-			24.92%	22.49%	<i>%</i>							
20%	-					18.24%	12.77%						
10%								6.69%	5.78%	4.86%	4.26%	4.26%	1.52%
0%													
	WALL	HTTR HE	SUCHIS	WILLIS.	COVE	WHO!	H.HOUSE	OTHER DO	N' KHOW	005 PR0	RIFTARY	¥HP8	HOHE

	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.

	Azu	re IoT	AWS	Google IoT							
Edge						Azure Io	T AW	7 S	Google IoT		
Storage	Blot SQL	o, CosmosDB,		0	Protocolli	MQTT, AM MQTT of	n on Webs	Socket,	MQTT, HTTP		
Big Data		$\overline{\mathcal{L}}$	7	7		WebSock HTTPS, AMQP o	,	.175			
Data Visualizatio	on Pow	ver Bi	•			WebSock	ret				
Artificial Intellig	gence	X	\times	X	Communication Patterns	Notificati	on, Notific	ation,	Telemetry, Query, Notification,		
Intelligence API	Intelligence API Language, Speech, Vision, Knowledge					Commar	nd Comn	nand	Command		
	Azure IoT	AW	rs	Google IoT		Azure IoT	AWS		Google IoT		
in bas	Prezzo Diverse fasce di prezzo in base al numero di messaggi scambiati		co Costo unitario per messaggio e per tempo di connessione del dispositivo		Scalability	Scaling da configurare mediante funzione	Servizio di scaling automatico	Servizio di scaling automatico			
	Azure IoT	AV	WS	Google IoT	Rimborsi	10% di rimborso fino al	10% di rimborso fino al		li rimborso fino al nella fascia fino al		
Sicurezza	TLS	TLS (mutual)		TLS	-	99%, al di sotto viene	99%, al di sotto viene	95% vie	95% viene restituito il 25% e al di sotto di questa il 50%		
Autenticazione	SAS Token, IAM, x.509	x.509, IAM, Amazon Cognito Federated Identities		o, JSON Token, IAM, x.509	_	rimborsato il 25%	rimborsato il 30%				

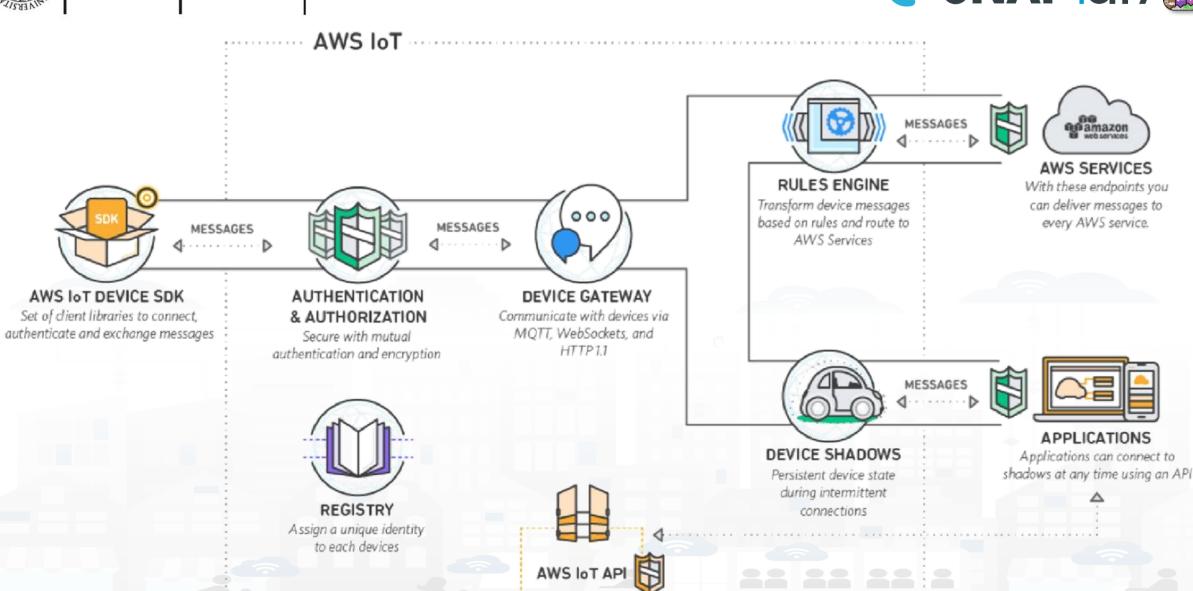
Snap4City (C), October 2025







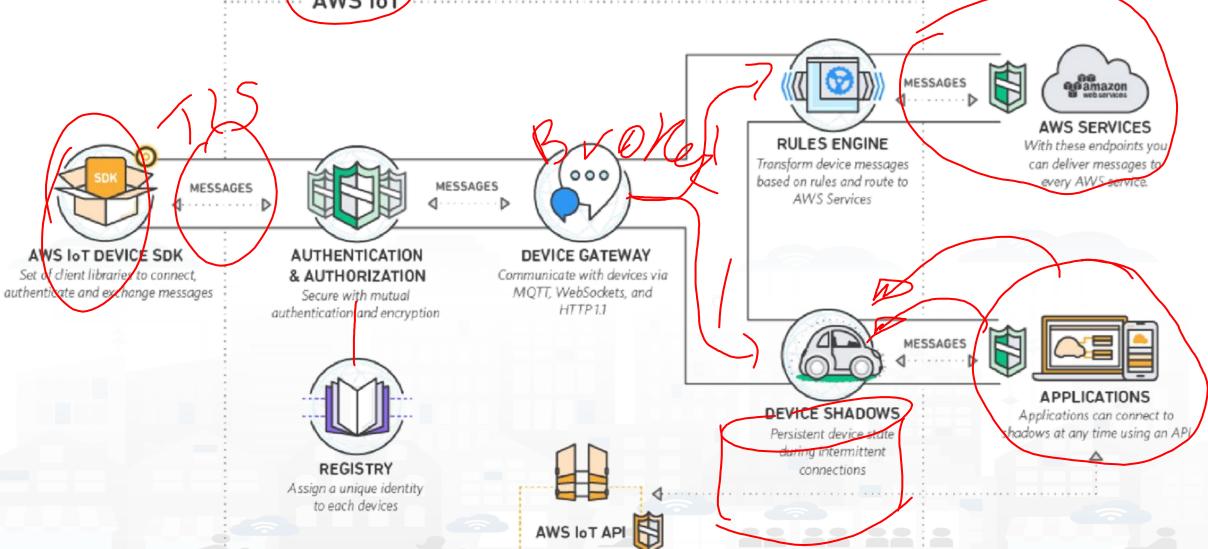












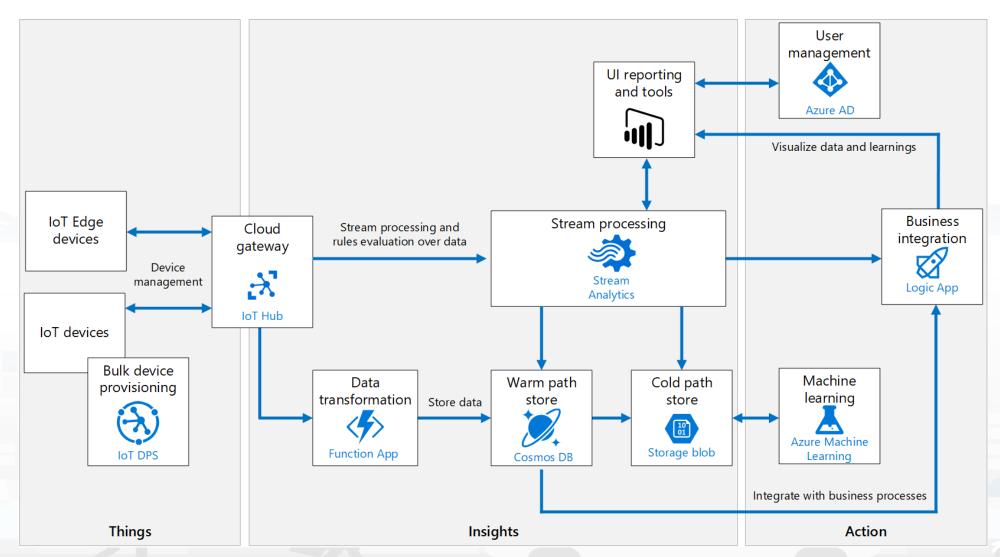








Azure Microsoft IoT (1)



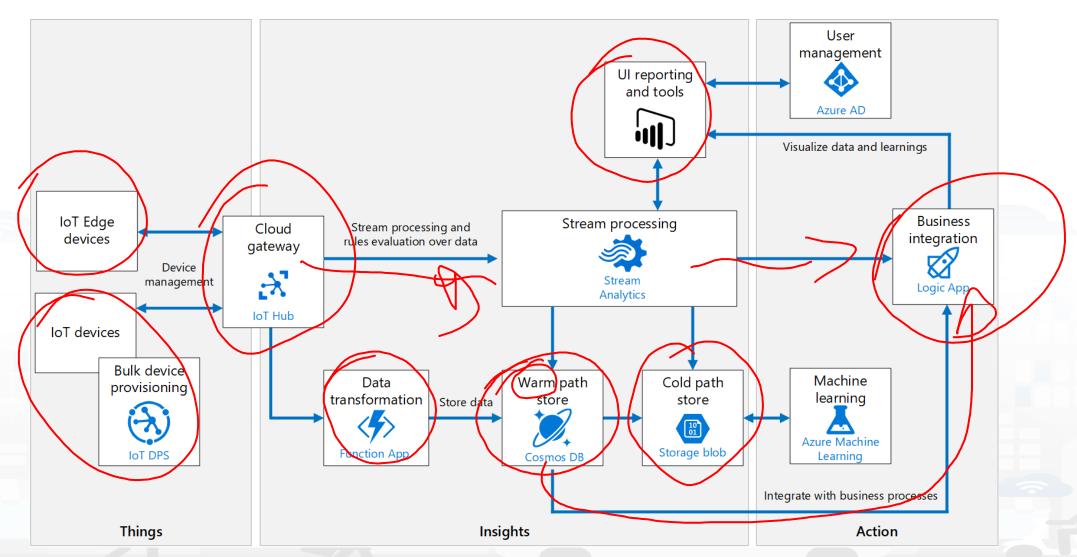




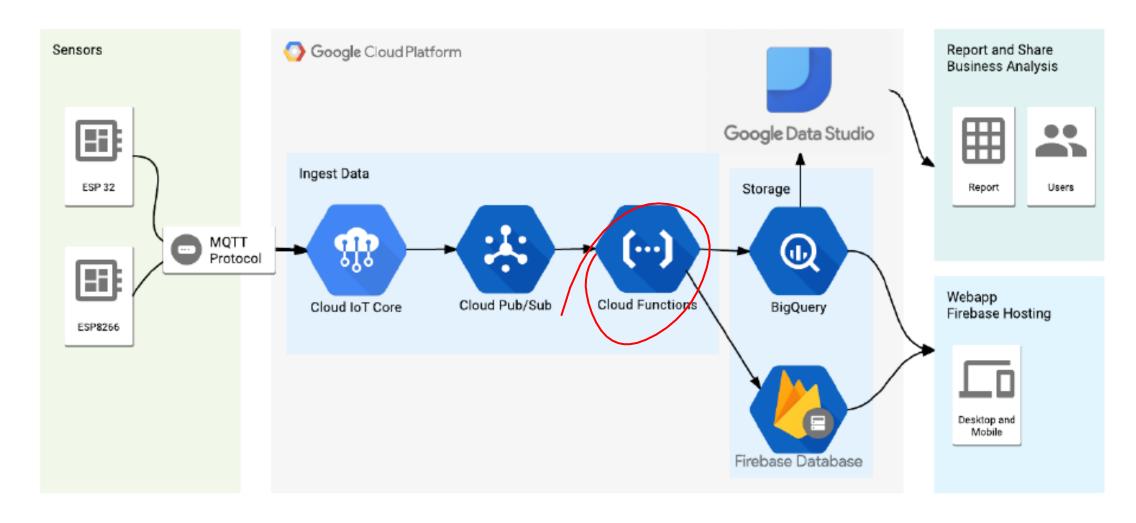




Azure Microsoft IoT (1)



Google IoT (1)

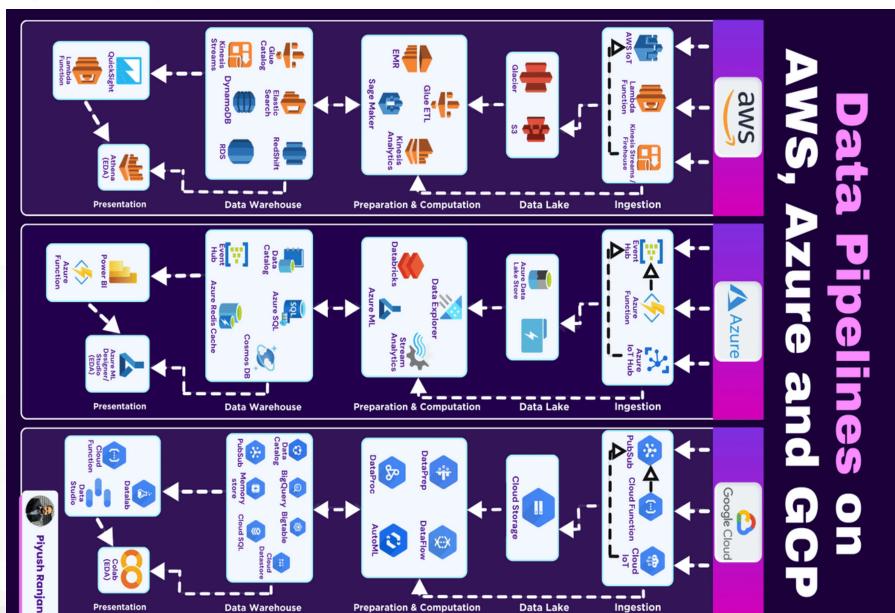








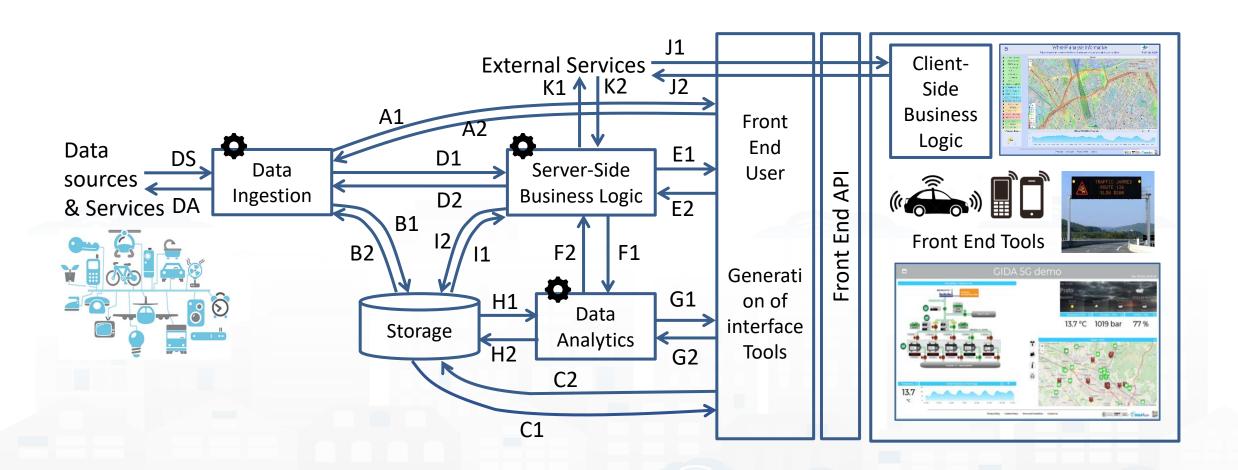








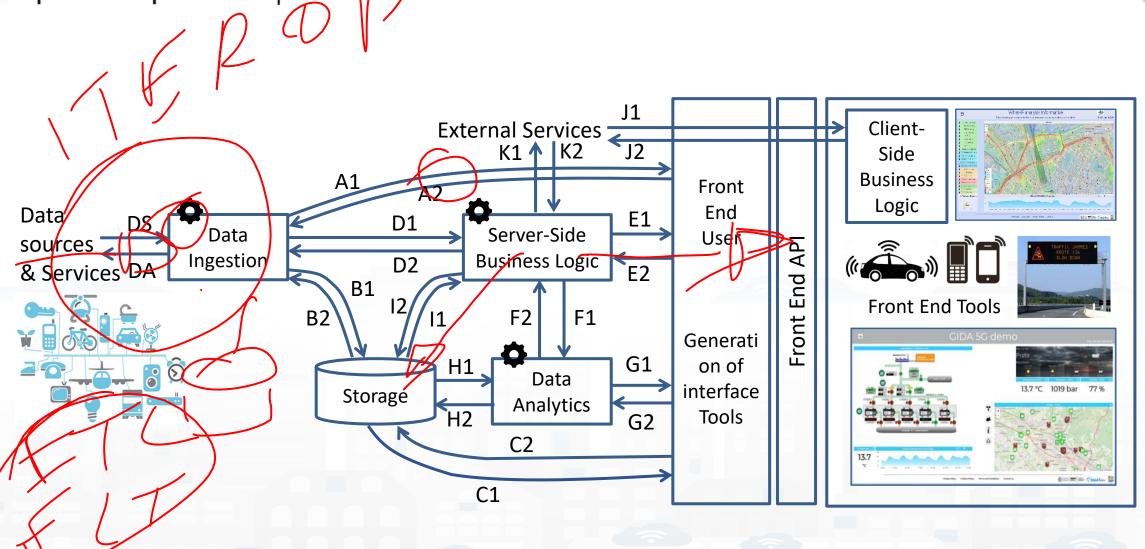












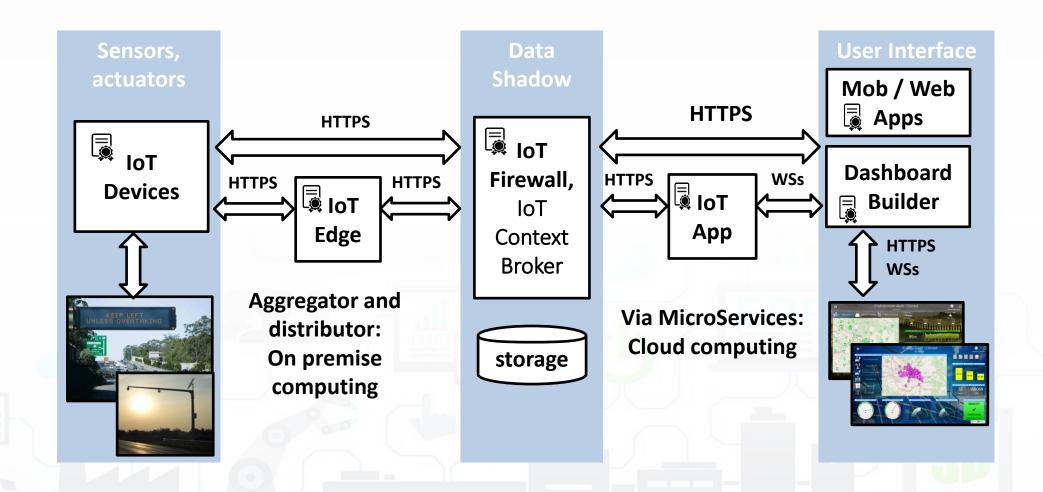




DINFO



The secure stack











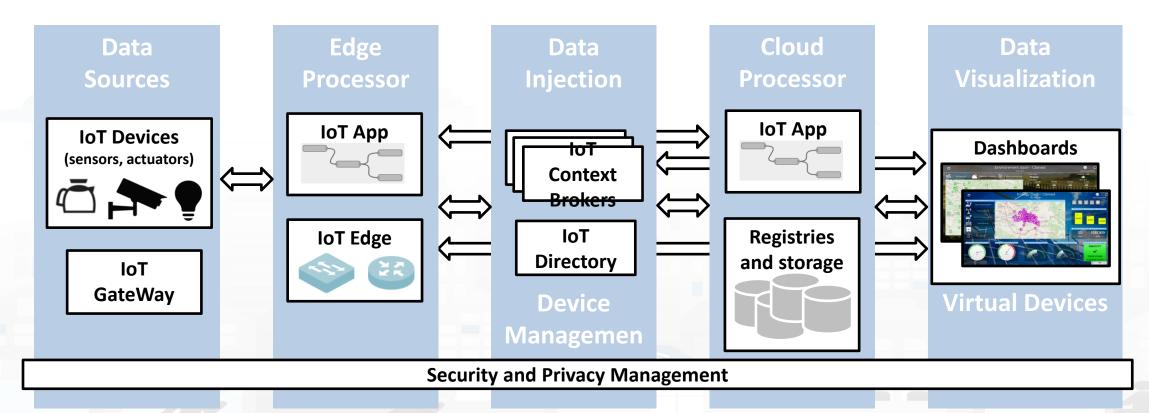
Complexity in Smart City IOT Platforms

End to End security

H2M

From IOT Devices to Dashboard (user interface)

M2M









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

Snap4City Architectures

https://www.snap4City.org

https://www.Km4City.org







SNAP4city AT THE SERVICE OF YOUR OPERATION AND PLAN THE POWER OF ARTIFICIAL INTELLIGENCE







SNAPADVISOR

www.snap4city.org

Powered by **S**FIWARE

FREE TRIAL









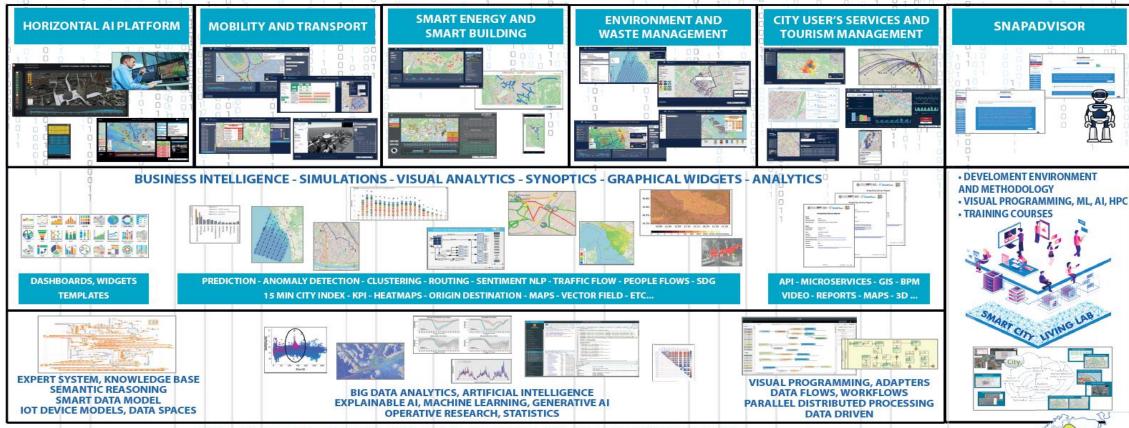












FULL INTEROPERABILITY, ANY: DATA, BROKERS, NETWORKS AND VERTICALS





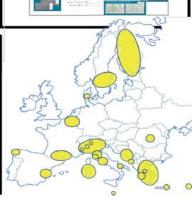
Smart Light

Smart Waste

Smart Energy

Smart Building

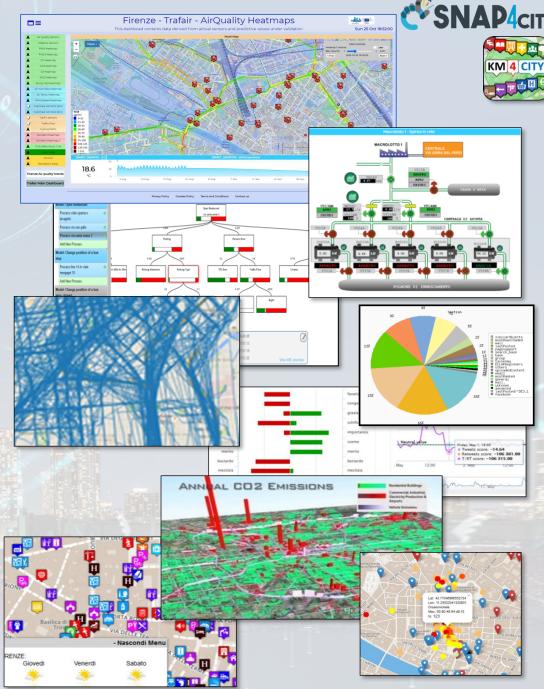
Smart Tourism



Data Driven Decision Support

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





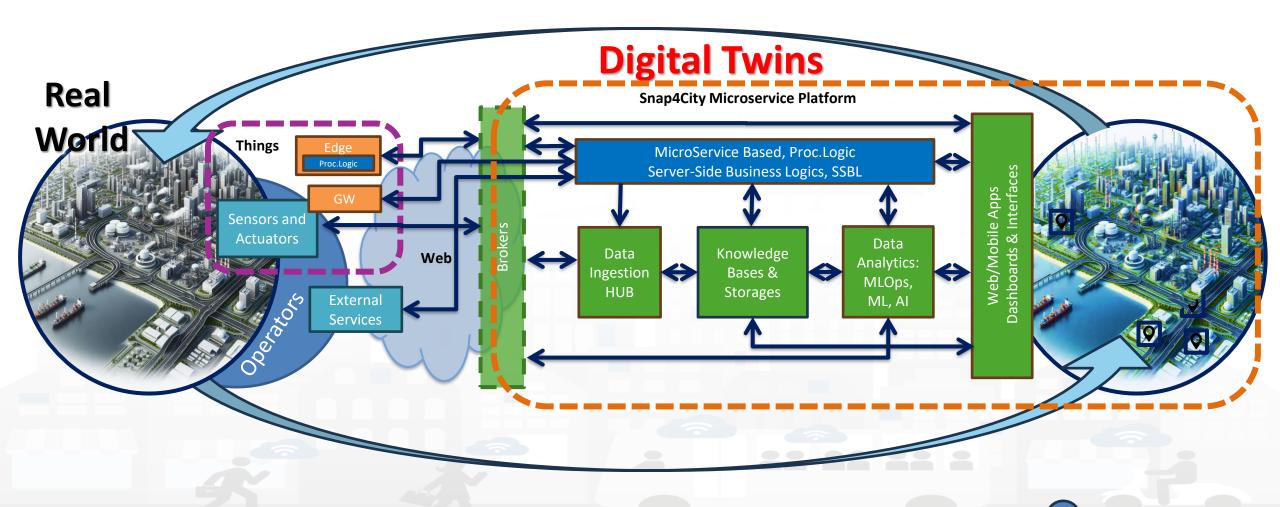








Digital Twin Development Platform



Ingestion, agg. -> exploitation



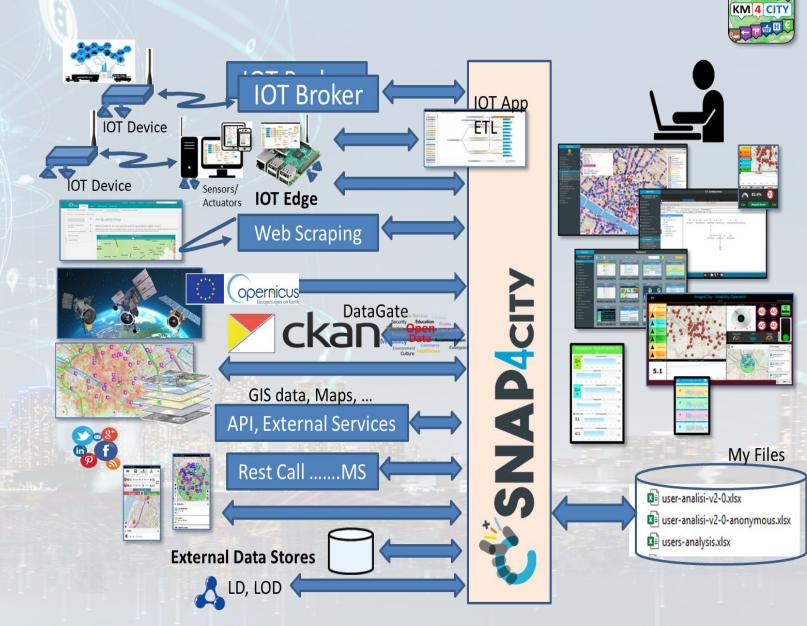






Snap4City efficient tools for

- Bidirectional data channels
- Any format, any channel, any data, any broker, any protocol, ...
- Km4City Knowledge base Ontology reasoning on geo, space, time, relationships



Expert System semantic queries

UNIVERSITÀ DEGLI STUDI FIRENZE DINFO





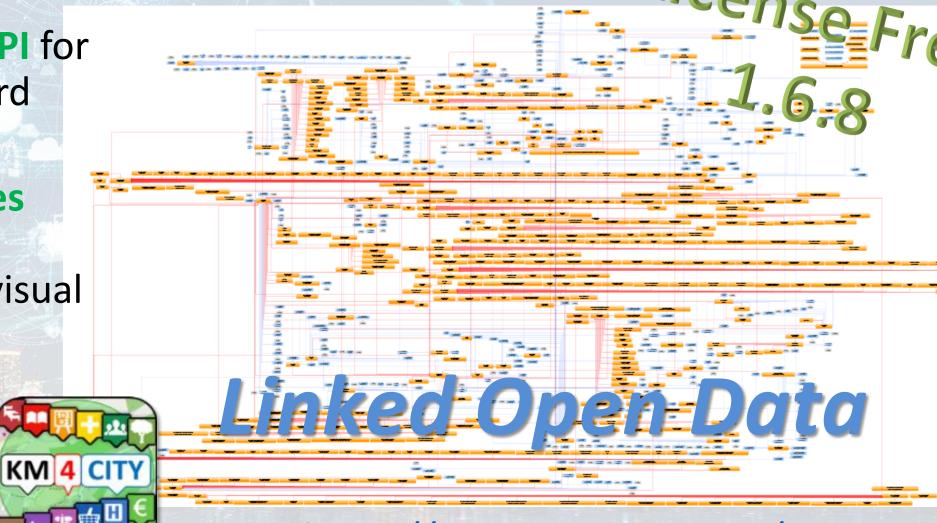
• via:

 Smart City API for Apps and third party

MicroServices
 data driven
 develop via visual
 language
 Node-RED







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 2025

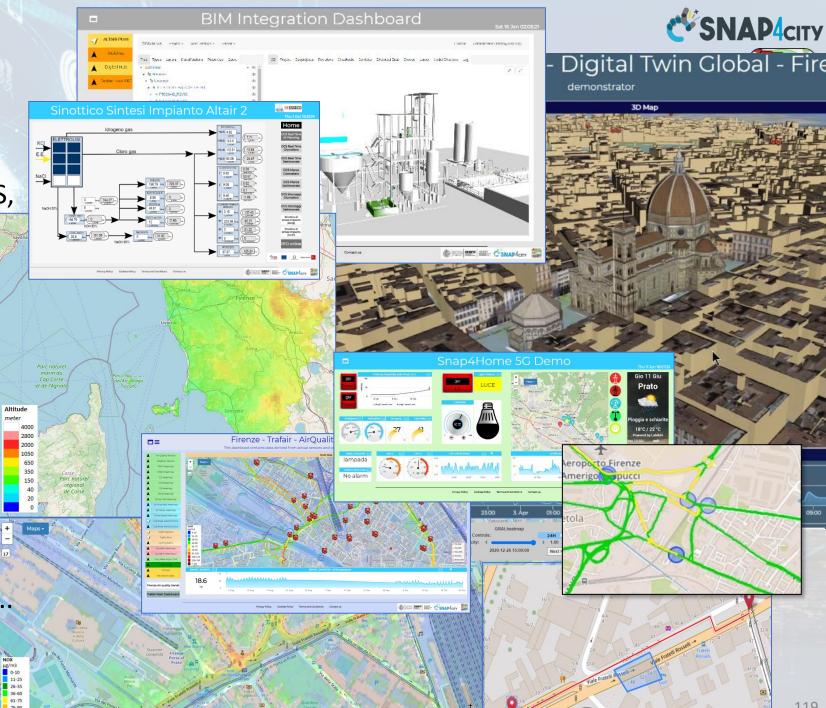
- POI, IOT Devices, shapes,...
 - FIWARE Smart Data Models,
 - IoT Device Models
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, ..
- traffic flow, typical trends, ..
- trajectories, events, Workflow, ...
- 3D Models, BIM, Digital Twins, ...
- OD Matrices of several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











Ingestion, aggreg. > exploitation

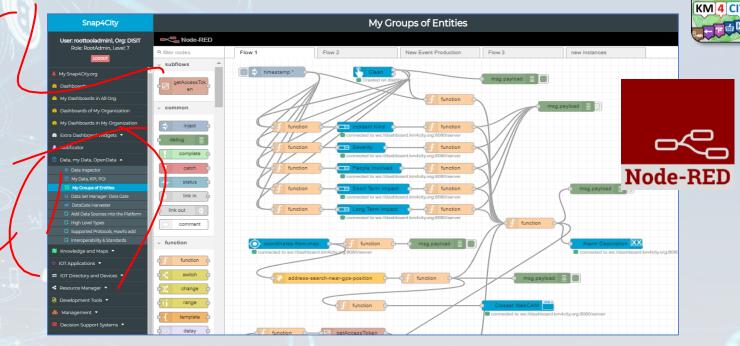


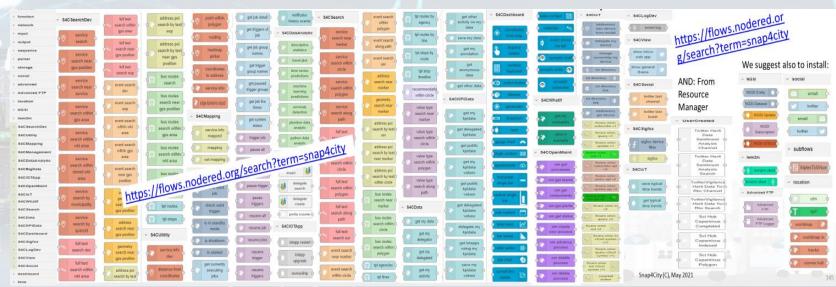






- IoT App Visual Programming, no coding
 - Data transformation
 - Integration
 - Scripting Data Analytics
 - Data ingestion
 - **Business logic**
- MicroServices data driven develop via visual language Node-RED













> 60.000 downloads (up to 2024)

Areas

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

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

Entities Managem_{enx} Visualitation service **Snap4City** Microservices M_{ana}gement P/atform Analytic Services Proc.Logic **SSBL** Third Party microservices

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**

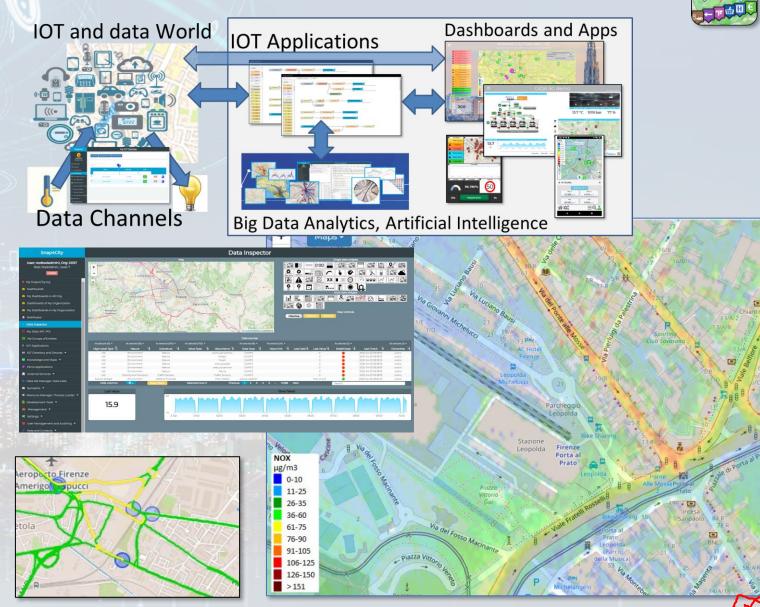
> **Dashboards** Widgets: Graphic Libraries **Interactive Widgets** Maps, 3D representations Synoptics, External Content Micro Web App

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

Solutions: reliable, secure and fast to realize

C'SNAP4CITY
KM4CITY

- 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



Data Analytics on Snap4City platform

tools

other

and

Base

Smart











Ontology Schema

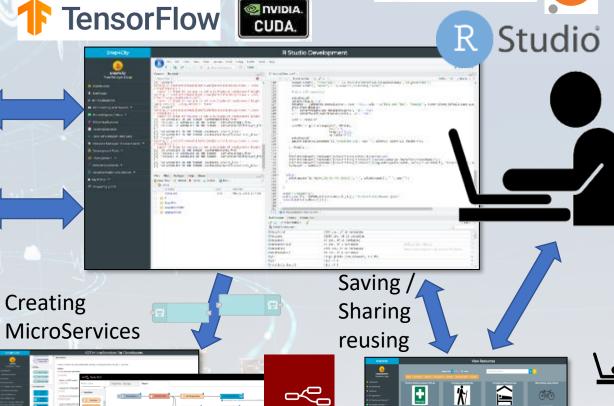


from Knowledge **Big Data** API **Store Facility** City





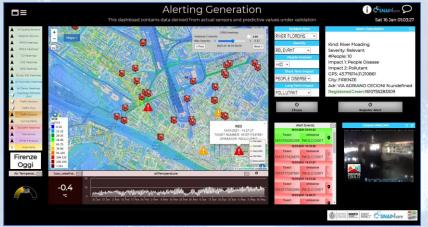
LOG.disit.org

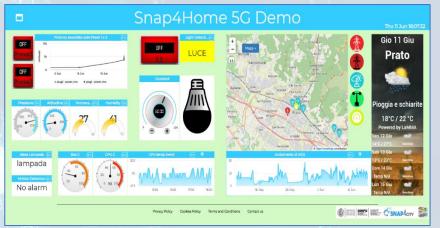


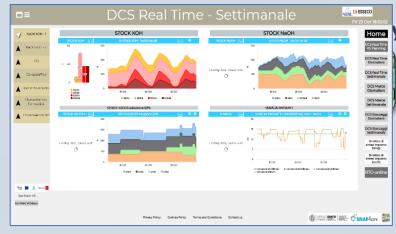
Node-RED

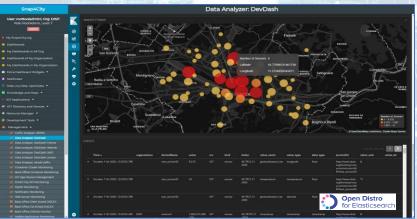
Using them into **IOT Applications** Resource Manager



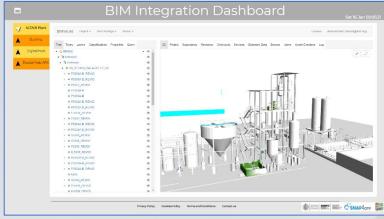




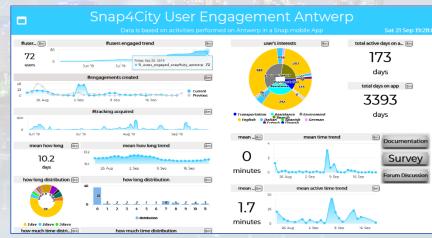


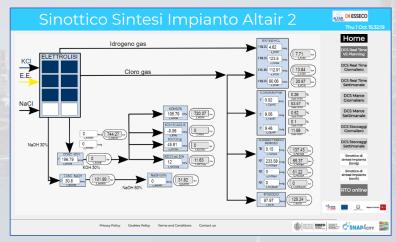








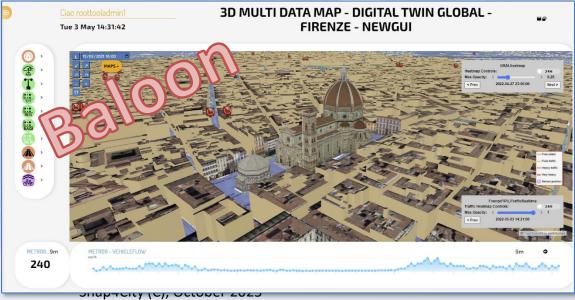




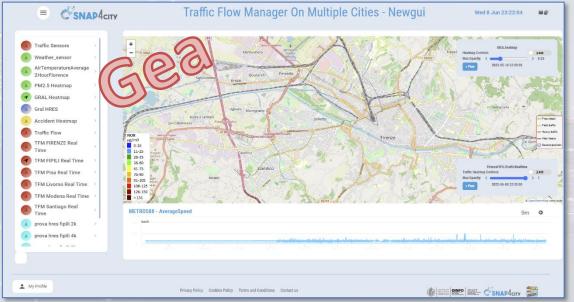
Different Themes































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: <u>Https://www.snap4city.org</u>
- https://twitter.com/snap4city
- https://www.facebook.com/snap4city

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

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



Tech Overview

https://www.snap4city.o rg/drupal/sites/default/f iles/files/Snap4City-PlatformOverview.pdf

















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-
- https://www.snap4citv.org

- https://www.snap4industrv.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









Development

https://www.snap4city.org/d ownload/video/Snap4Tech-**Development-Life-Cycle.pdf**



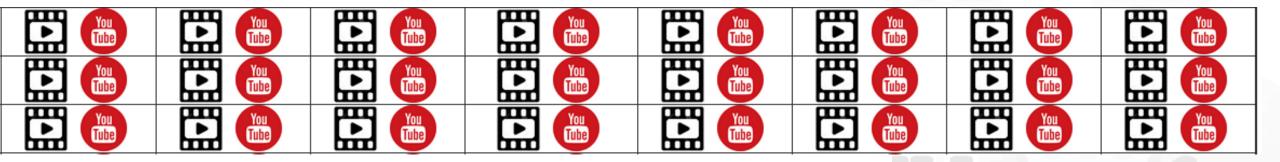
https://www.snap4city.org/944

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 Develo Smart Solutions
GENERAL ACTIVITIES OF THE PARTY	Canadan Santa Barbara	CEMANATOR STATES	CENANOR STATE OF THE PROPERTY	C SNA34m	CONANTON DE CONANT	CENANTON DE CONTROL DE	CENANTOR CONTROL SAME CONTROL S
CSHAP4ory Superior Stocks To the stock of t	C'ENAMON E SOURCE DE SELECTION	C SHAPACITY CONTROL OF SHAPE CONTROL OF	CERASACTO STATE OF ST	CEMANAGE STATE STA	SHADAGOV STATE OF STA	SHAPAGIN SHA	CEMANAGE STATE OF STA









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

Interoperability

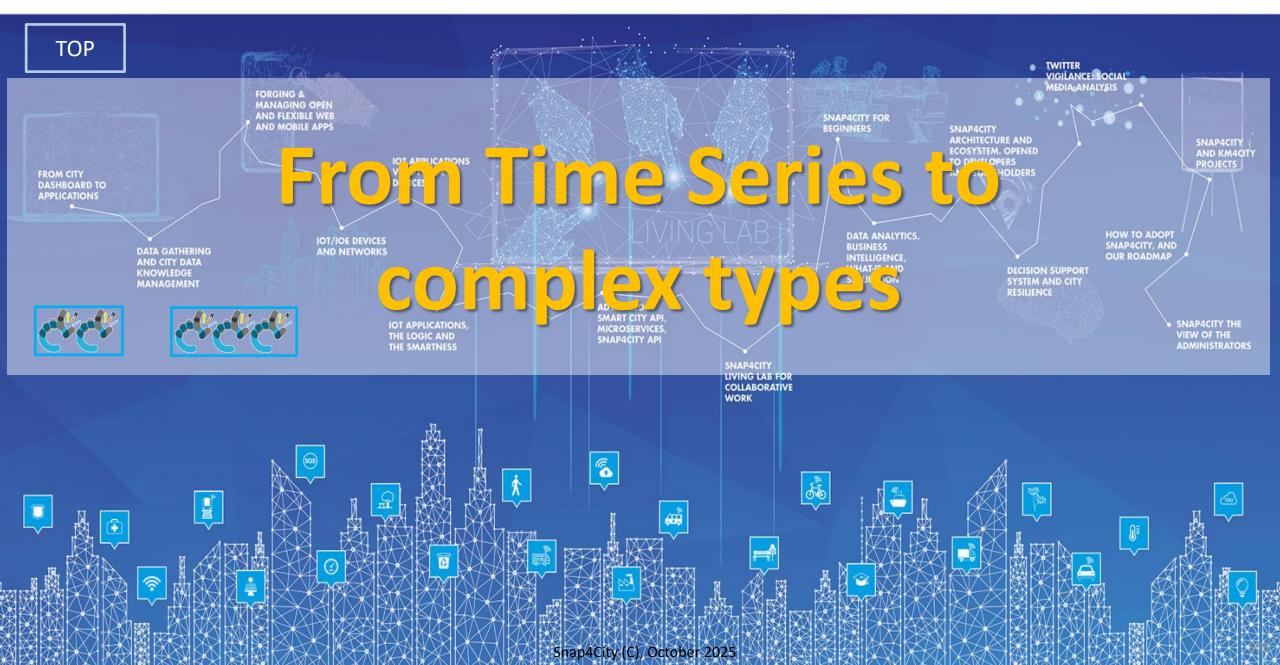
https://www.snap4City.org

https://www.Km4City.org



SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES

















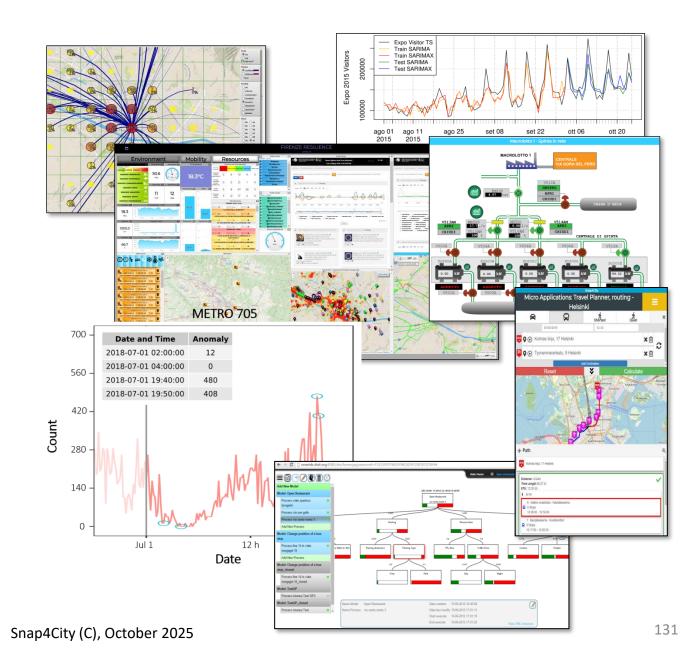




Control Room

- 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

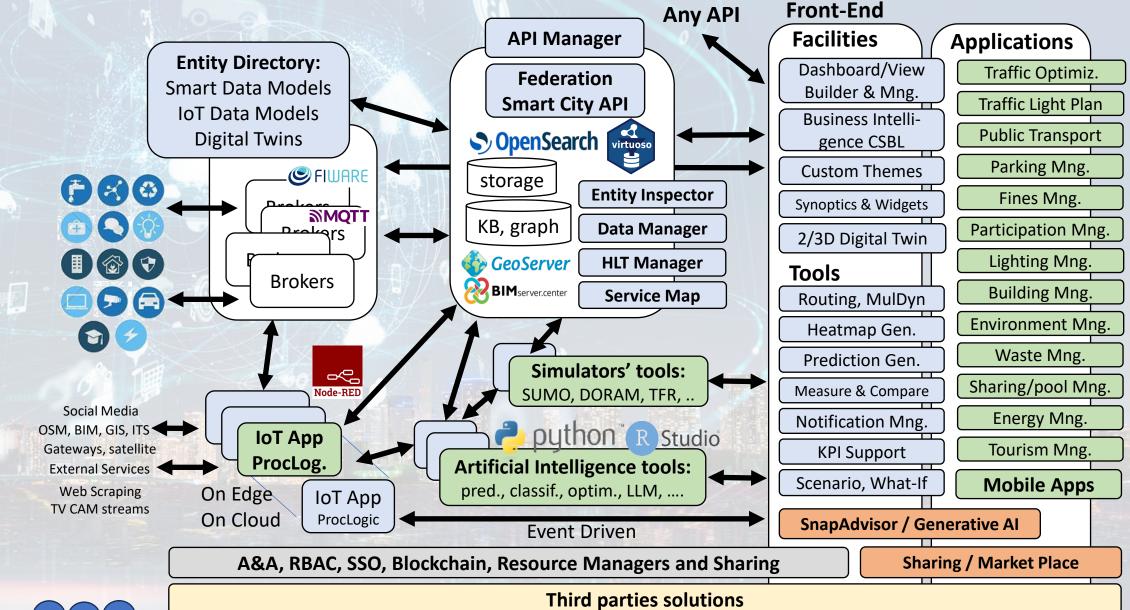
From strategies to Actions



Technical Architecture







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, gITF, 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.







Snap4City (C), October 2025



















https://www.snap4city.org/65





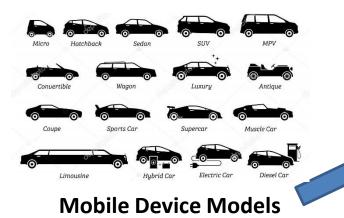






Mobile Devices







Mobile Device

- Name:....

- Model:....
- Spec:...
- 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»

Mobile Device Variables

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













Sensor/Sensor-Actuator









Sensor Device

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

Sensors

- dateObserved:
- 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..





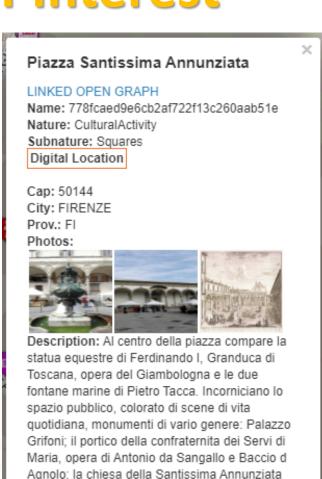






POI, Point of Interest

- 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



con il portico del XVII secolo; I ospedale degli

Innocenti del Brunelleschi







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







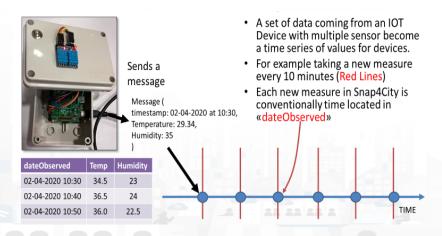




Data Ingestion Stragey

- 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







Dashboards

Notificator

Load WKT on ServiceMap (Antwerp

UNIVERSITÀ **DEGLI STUDI** FIRENZE

http://www.disit.org/km4city/resource/Firenze1610780220000

KB, ServiceMap





Snap4City (C), October 2025

0 8 0

High Level Types

Snap4City (C), October 2025

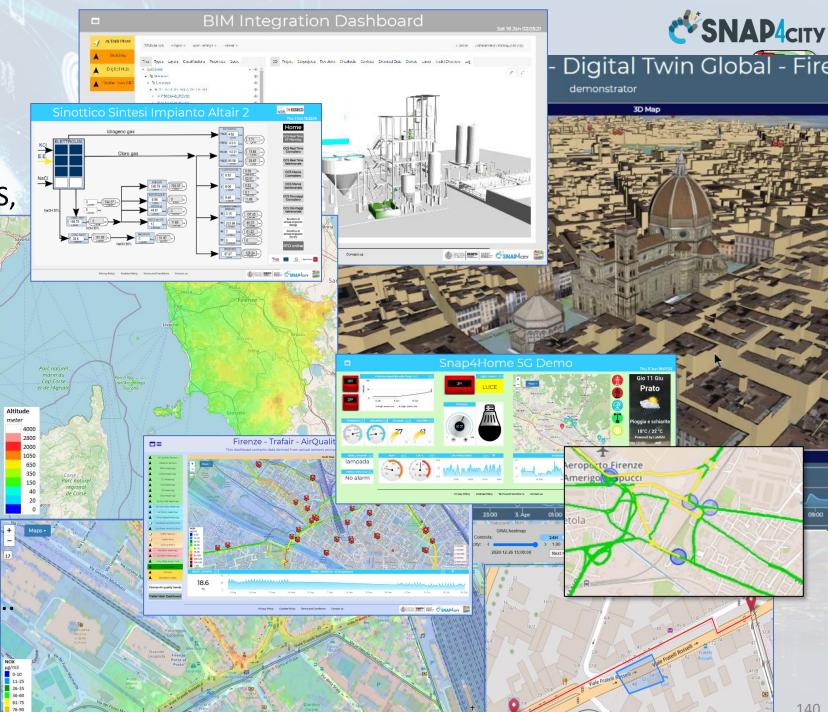
- POI, IOT Devices, shapes,...
 - FIWARE Smart Data Models,
 - IoT Device Models
- GIS, maps, orthomaps, WFS/WMS, GeoTiff, calibrated heatmaps, ..
- Satellite data, ..
- traffic flow, typical trends, ...
- trajectories, events, Workflow, ...
- 3D Models, BIM, Digital Twins, ...
- OD Matrices of several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











SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES

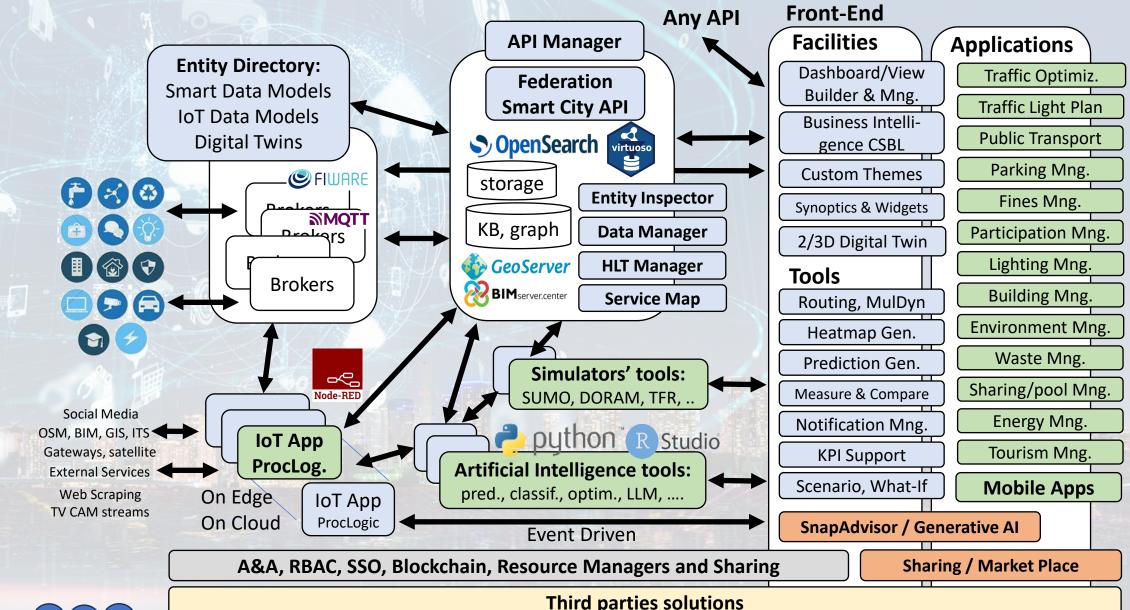




Technical Architecture







Standards and Interoperability

SNAP4city

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.



















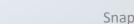


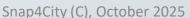




https://www.snap4city.org/65



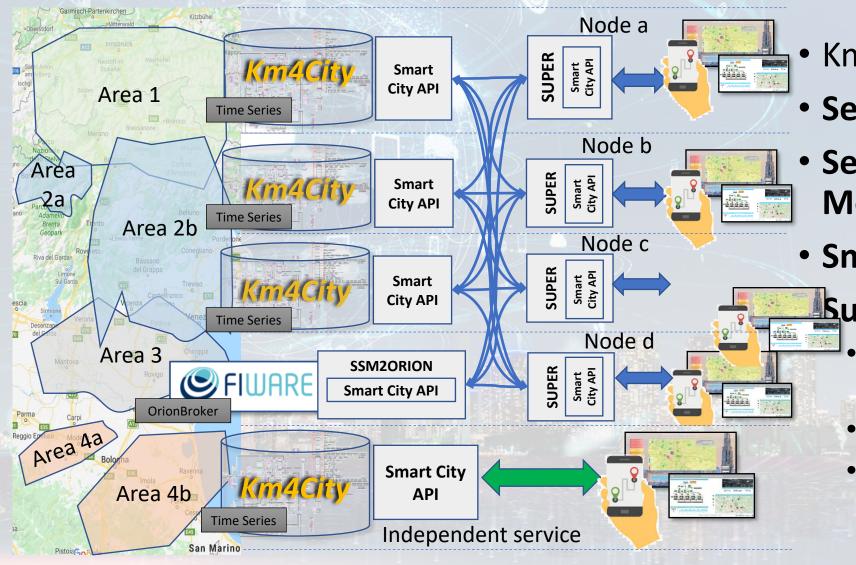




Federation of Smart City Services







- Km4City **Semantic Reasoner**
- ServiceMap interoperability
- Seamless for multiple **Mobile Apps**
- Smart City API

Super:

- distributed access and sharing services
- Each city control its own data
- Final user can pass from one city / area to another in seamless manner: without changing the mobile Apps









TOP

Dictionary for Data Fields Semantics and Technical Meaning





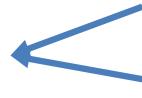






Unified Data and Services Model/Classification

Semantic Nature



SubNature SubNature

Technical meaning

Value Type

Value Unit

Value Unit

- 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





Power Value Type

Value Unit Value Unit

mW

URL

KW

Data Type

Integer

Data Type

Float

Link to Friend Sensor as ServiceURI: Value Type

Value Unit Value Unit

KW

Data Type

String, URL

Data Type

Float









Example of Energy and its Value Units







Please note on: Data Type

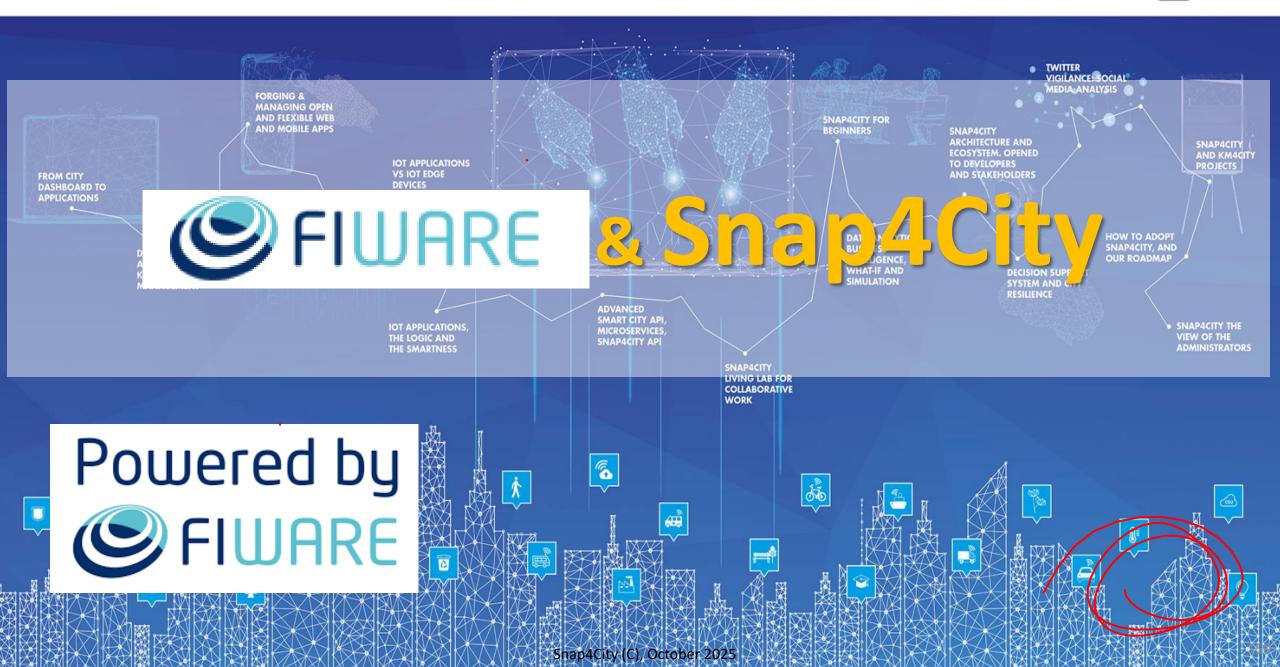
- Value Types have only a few number of **Data Types** because they represent how the data area treated into the system
- Therefore main Data Types are:
 - Float: numbers with decimals large as you like, etc.
 - Integer: numbers, booleans (0/1), etc.
 - String: url, links, names, id, descriptions, status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

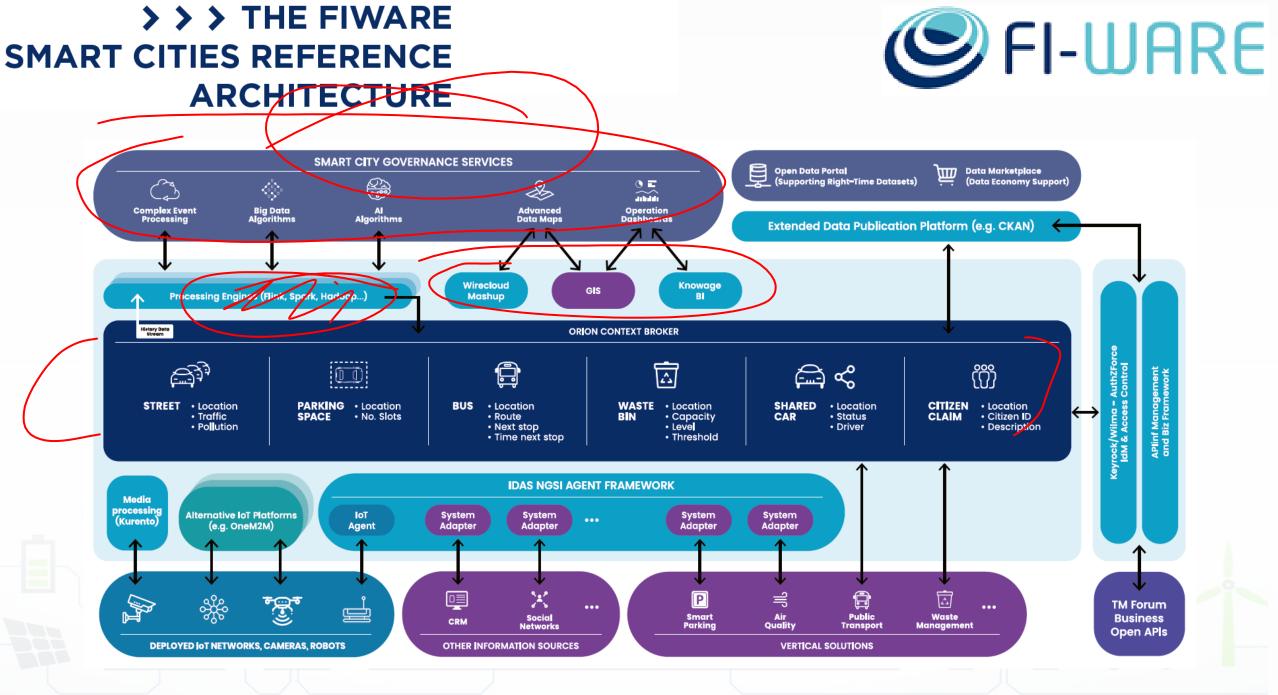
—

SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES























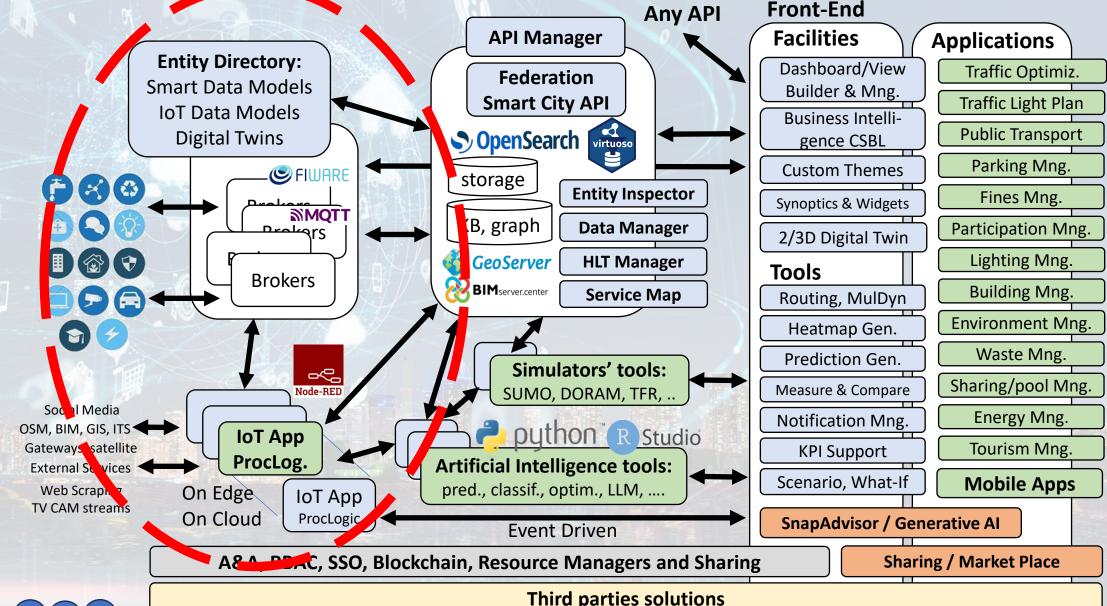
- Snap4City Powered by <u>FIWARE</u> Solution & Platform:
 - https://www.fiware.org/marketplace/product-details/?category=powered&id=snap4citysnap4city
 - NGSI V1, V2 The IOT Orion Broker
 - IOT Orion Broker can connect JSON, MQTT, Lightweight M2M, LoraWAN, OPC, SigFOX, etc. see FiWare https://www.fiware.org
- Snap4City FIWARE Training Services:
 - https://marketplace.fiware.org/pages/solutions/03bccd83a0e1b0398ba7a
- Snap4City FIWARE Consultancy Services:
 - https://marketplace.fiware.org/pages/solutions/907f5ecc63927f643dd8421
- 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



Technical Architecture





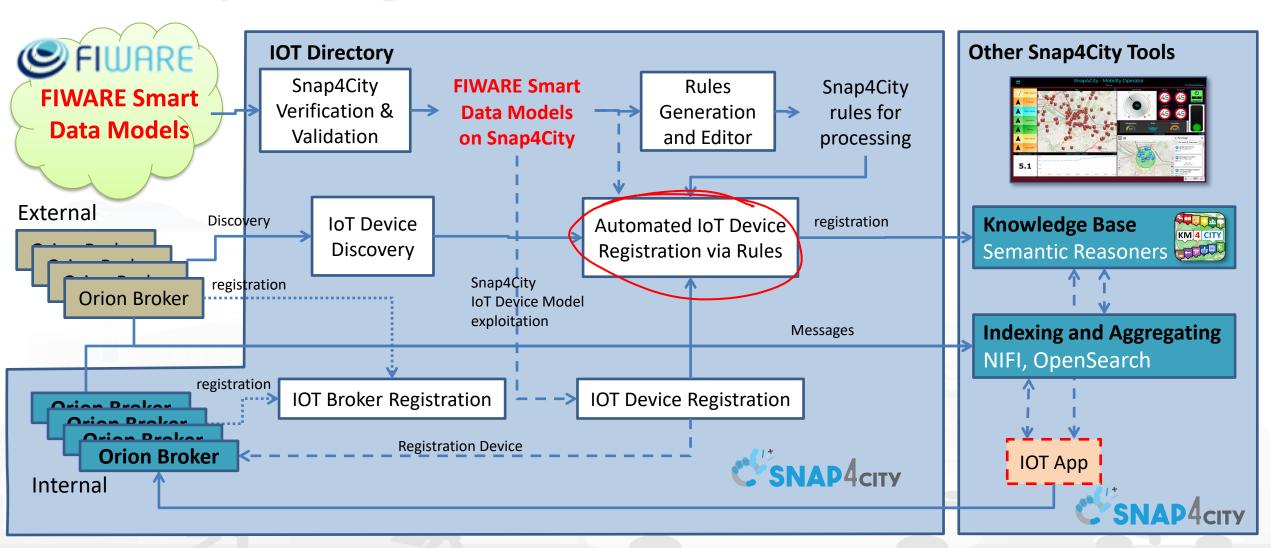








Exploiting FIWARE Smart Data Models



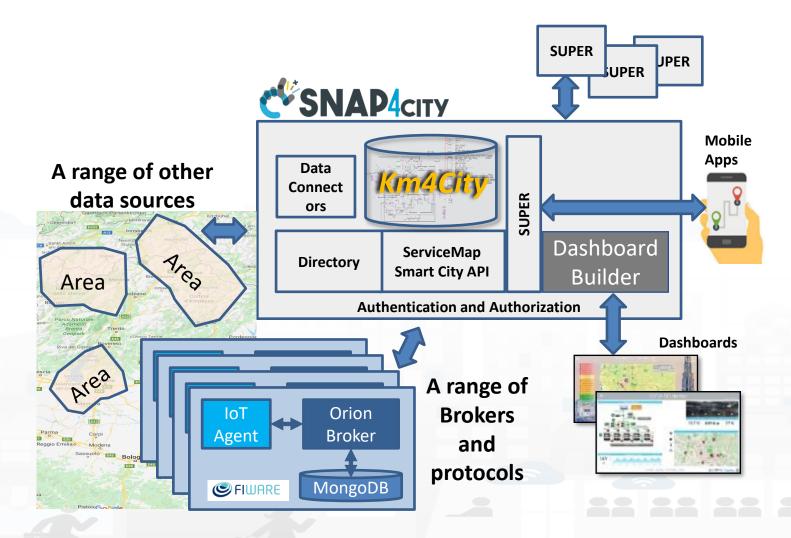








Snap4City IoT Registration and Access



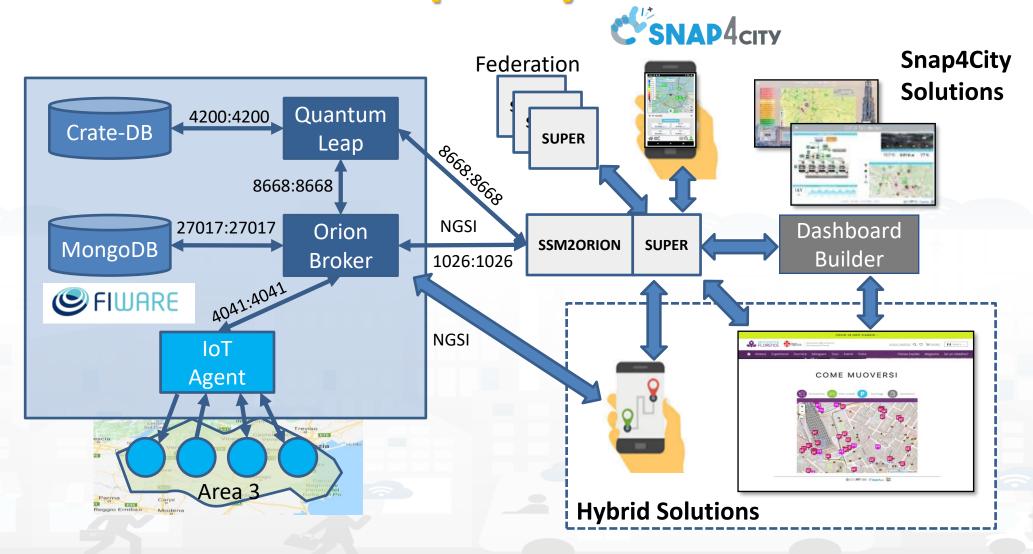








Federation of Snap4City vs ORION Broker









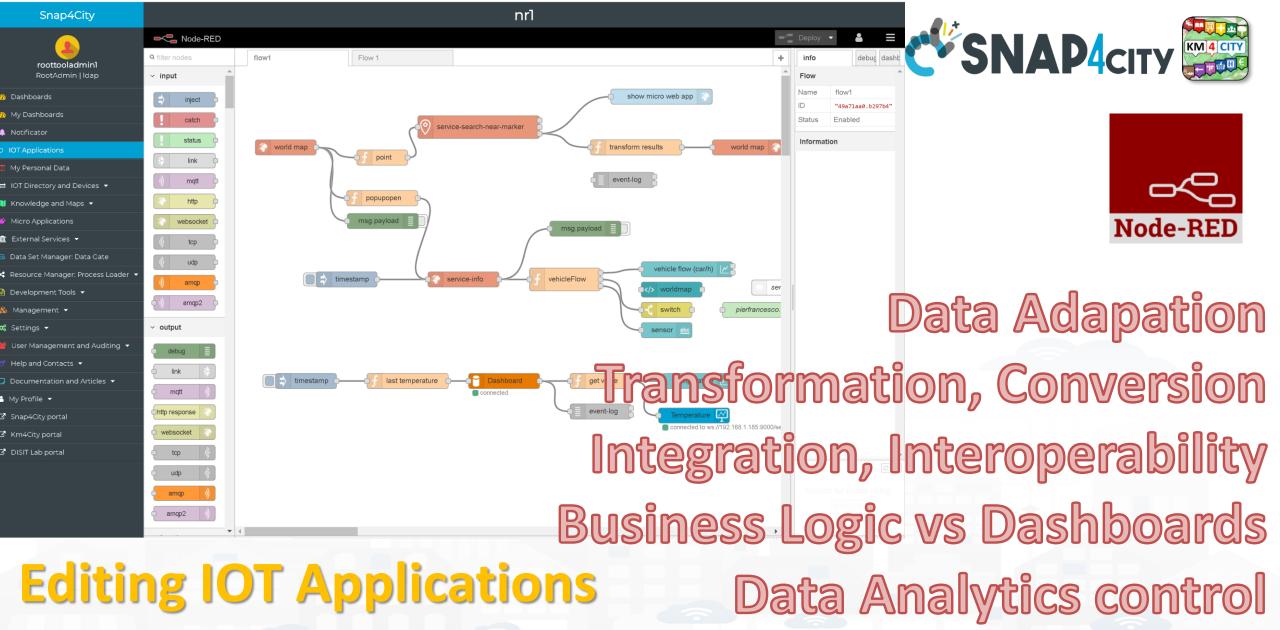
https://www.disit.org/
Paolo Nesi, paolo.nesi@unifi.it

IoT App / Proc.Logic

https://www.snap4City.org

https://www.Km4City.org





Everywhere: Cloud, on loT 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



INGEGNERIA DELL'INFORMAZIONE

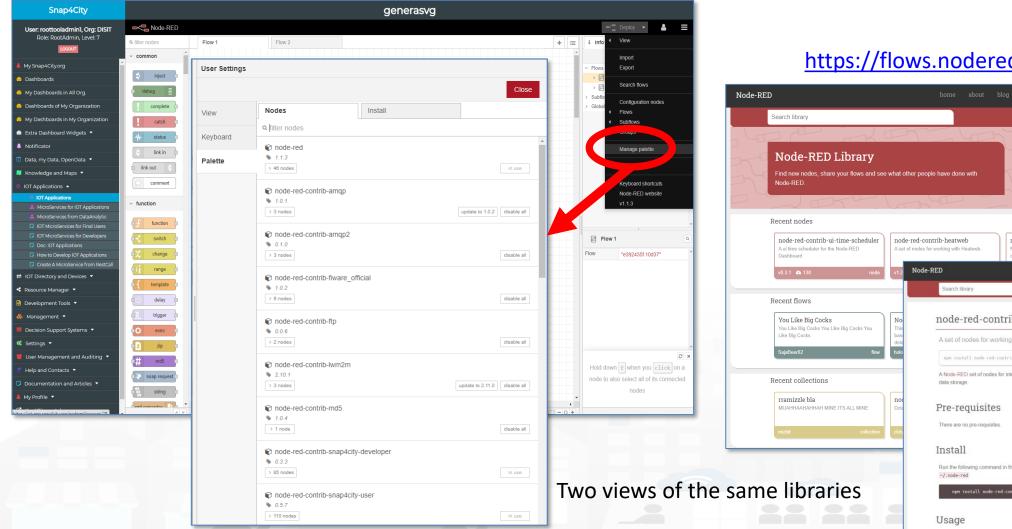




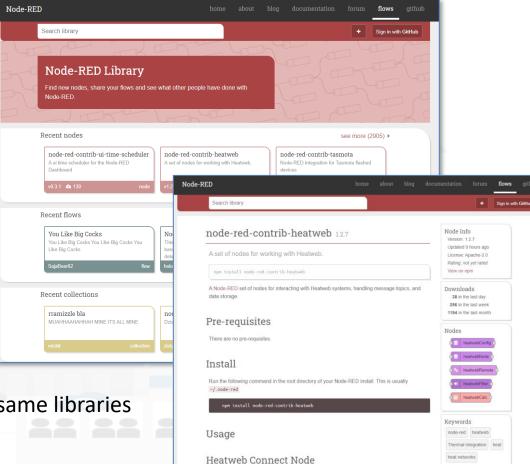


Load Library from Palette





https://flows.nodered.org/



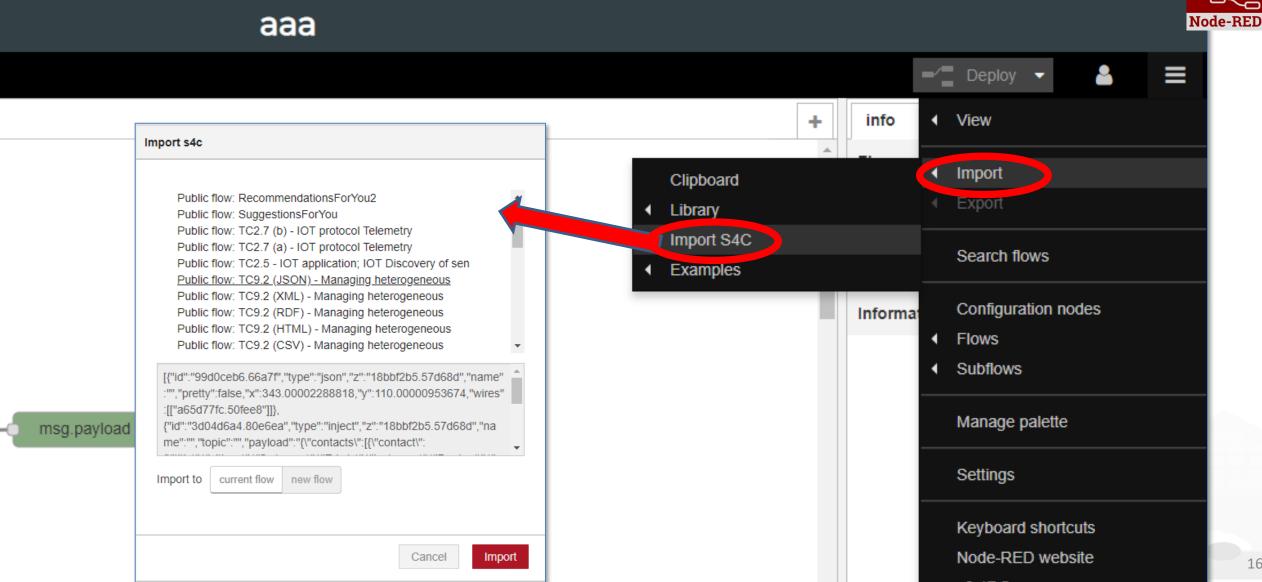




SNAP4city KM4 city













MicroServices SNAP4city





Areas

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

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

Entities Managem_{enx} Visualitation serile **Snap4City** Microservices M_{ana}gement P/atform Analytic Services Proc.Logic **SSBL** other Third Party microservices

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**

> **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.

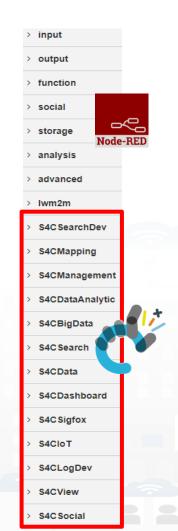


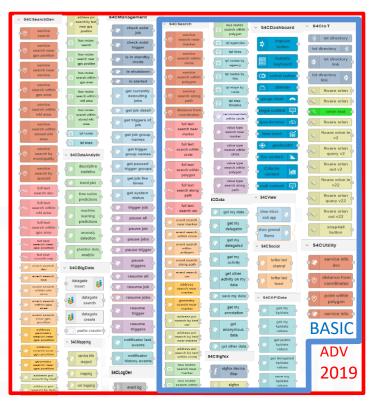




IOT Applications = Node-RED + Snap4City Platform

- 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

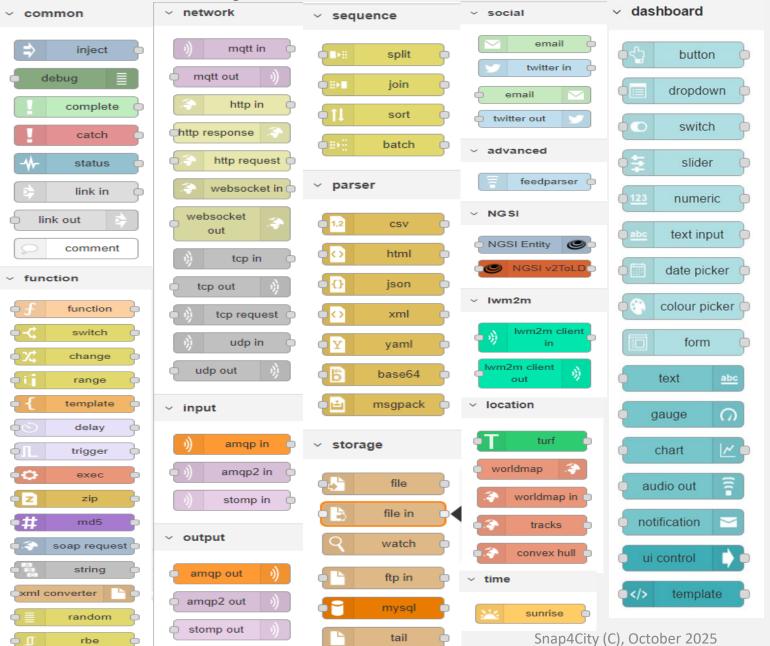
node-red-contrib-snap4city-developer
Node-red nodes for developing IoT applications for smart cities. These nodes are

node-red-contrib-snap4city-user
Nodes for Snap4city project, targeted to
standard user (no developer)

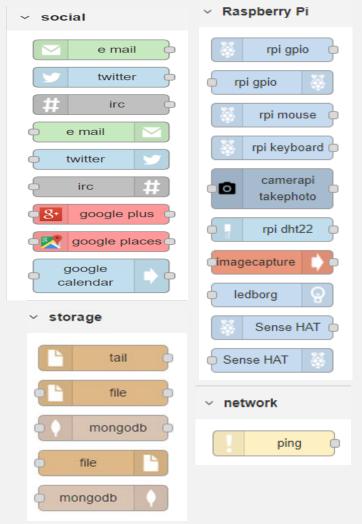
v0.2.0 27 5.0 (1.6)

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





+ on IOT Edge Raspberry









- **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



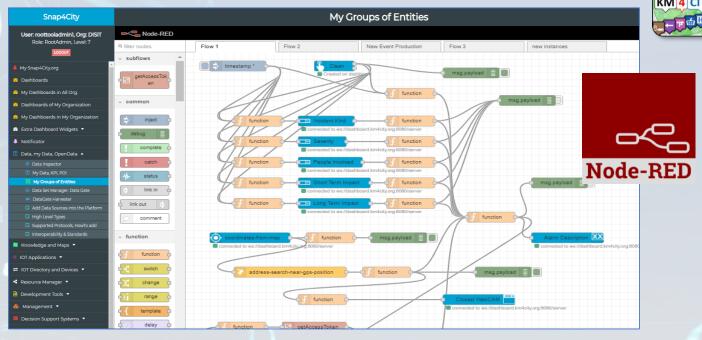


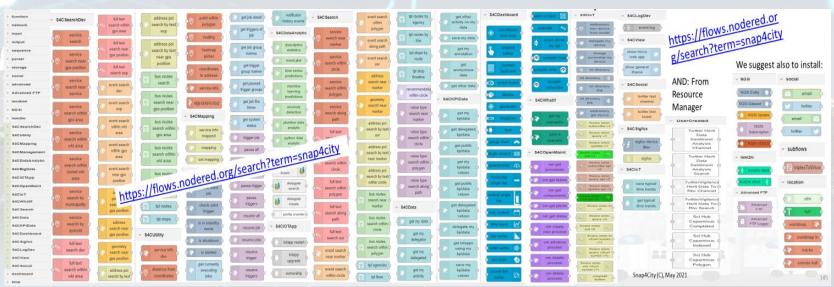




• IoT App Visual Programming, no coding

- Data transformation
- Integration, Interoperab.
- Scripting Data Analytics
- Data ingestion
- Business logic
- Edge and Cloud
- MicroServices data driven develop via visual language Node-RED







> time

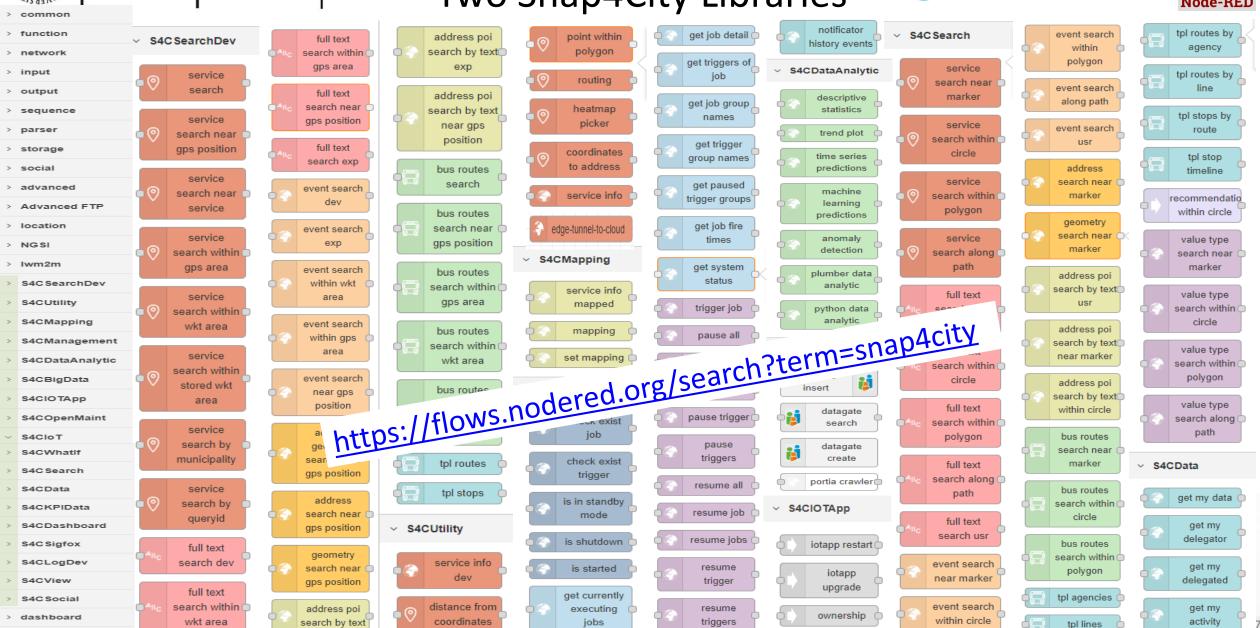
INGEGNERIA **DELL'INFORMAZIONE**

DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

2024 collection Two Snap4City Libraries









DELL'INFORMAZIONE

O

◐

S4CDashboard

from - map

impulse -

button

numeric

keyboard

switch -

button

dimmer

geolocator

dropdown

form

gauge - chart

single -

content

speedometer

horizontal -

single - bar

vertical -

single - bar

web - content

time - trend

bar - series

radar - series

pie - chart

curved - line -

series

2024 collection



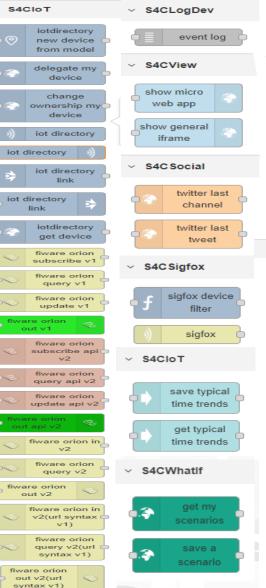




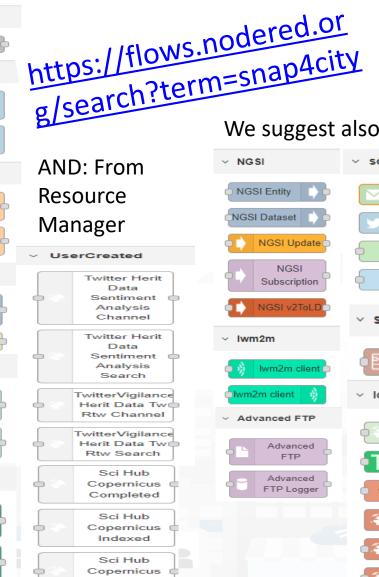
> time



process



snap4all



Polygon

We suggest also to install:



Snap4City

IOT Applications

User: roottooladmin1, Org: DISIT Role: RootAdmin, Level: 7

- Oashboards
- My Dashboards
- Notificator
- O IOT Applications
- My Personal Data
- ☐ IOT Directory and Devices ▼
- Knowledge and Maps
- Micro Applications
- External Services
- Data Set Manager: Data Gate
- Resource Manager: Process Loader
- Management ▼
- User Management and Auditing ▼
- □ Documentation and Articles ▼
- My Profile ▼
- ☑ Snap4City portal
- ☑ Km4City portal
- ☑ DISIT Lab portal



2018-10-22T11:57

Deprecated - SiiMobilityControlRoom

owner: badii

Management

Management



Prev 1 2 3 ... 9 Next







Filter

Q













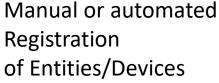


Python, ...



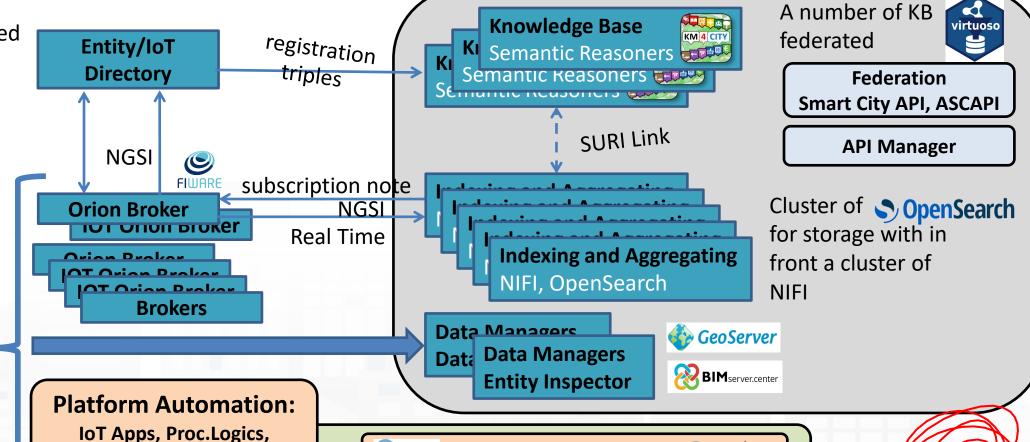
Snap4city Data Ingestion Diagram

storage



Massive data flow entering

Massive data flow exiting



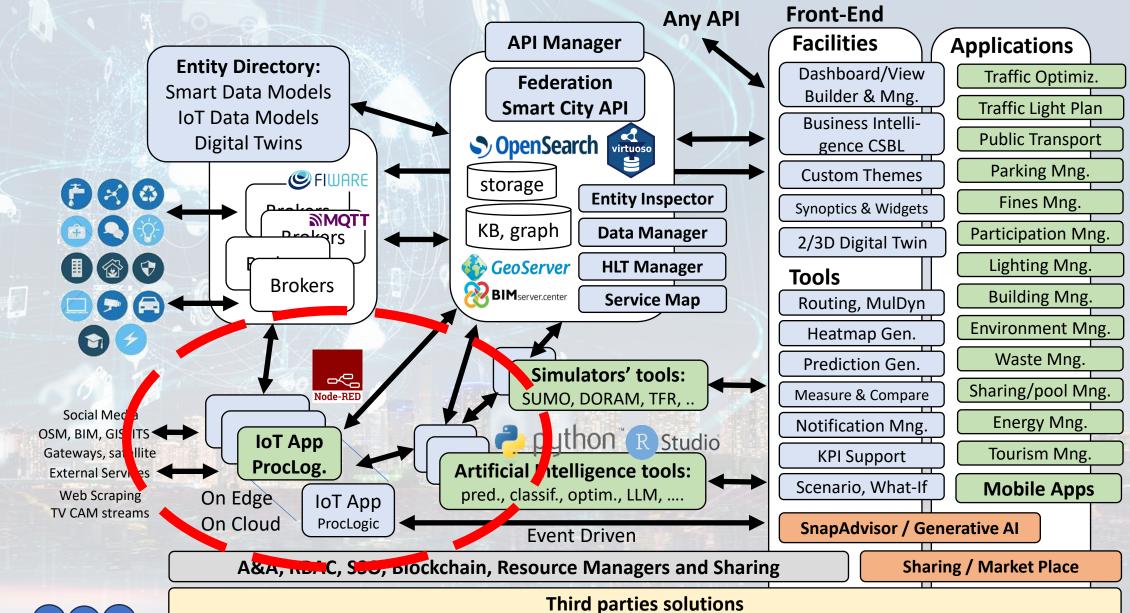
R Studio Data Analytics: ML, AI, XAI 🦰 python

Platform Control and Management

Technical Architecture







OT Discovering

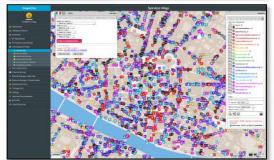


Proc.Logic / IoT App Development

MicroServices collections My IoT Applications









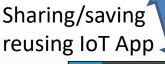
ServiceMap Discovery



Dashboard Collection, Editor and Wizard



Generating IoT App With Dashboard





Resource Manager











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

Comparisons

https://www.snap4City.org

https://www.Km4City.org







DISIT DISTRIBUTED SYSTEMS MAIN INTERNET TECHNOLOGIES LAB MAIN CARLES AND INTERNET TECHNOLOGIES AND INT



	Open Source end-to-end	Scalability IOT	Execution scalability	Visual Programming end-to-end	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	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Y	Υ	Υ	Υ	Υ
KAA	Υ	Υ	Υ	N	Υ	N	Υ	N/Y	Υ	N		Υ	Υ	N	Υ
AWS	N	Υ	Υ	N	N	N	Υ	Υ	N	Υ	Υ	Υ	Υ	(Y)	Limited
Azure IOT	N	Υ	Υ	(Y)	N	N	Υ	Υ	(Y)	Υ	Υ	Υ	Υ	(Y)	Limited
IOT IGNITE	Υ	Υ	N	Υ	N	N	Υ	N	N	N		N	Υ	(Y)	MQTT
PTC ThingWorkx	N	Υ	(Y)	Υ	N	N	Υ	Υ	N	N		Υ	Υ	(Y)	Υ
BEZIRK	Υ	N	N	N	N	Υ		Υ	N	N		N	N	N	Υ
Bosch IoT Suite	N	Υ	(Y)	Υ	Υ	N	Υ	Υ	N	N	Υ	Υ	Υ	(Y)	Υ
FIWARE ref SC arc.	Υ	(Y)	N	N	Υ	N	N	Υ	N	N	N	N	Υ	N	Υ
CISCO Jasper	N	Υ	N	N	N	N	Υ	N			Υ		Υ		N
IBM Watson IoT	(N)	Υ	(Y)	Υ	Υ	Υ	Υ	Υ	N	Υ	(y)	Υ	Υ	Υ	Υ
Siemens MindSphere	N	Υ	900_	Υ	N	N	N	Υ	N	N	Υ	N	Υ	N	Υ
Carriots	N	Υ	000	N	N	N	Υ		N	N	1	N	Υ	Υ	MQTT
Thingsboard	Υ	Υ	N	N	N	N	N	N	N	N		Υ	Υ	Υ	(MQTT, CoAP, http)
IOT eclipse.org	Υ	Υ	N	N	N	N	Υ	Υ	N	N	N	N	N	N	Υ
Google IOT	N	Υ	Υ	N	N	N	Υ	N	N	N	N	Υ	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	Υ	N	Υ	(Y)	Υ	Υ
Connect External and Internal Brokers	Υ	Υ	Υ	Υ	Υ	(Y)
Use any Data Model with any data type	Υ	Υ	(Y)	(Y)	Y	(Y)
Verify the correctness of IoT Messages of IoT Devices	Υ	(Y)	(Y)	(Y)	(Y)	(Y)
Semantic Interoperability	Υ	Υ	Υ	Y	Y	(Y)
Automatics deploy of Internal IoT Brokers	Υ	N	N	N	N	_ Y
Register External Brokers	Υ	N	N	N	N	N
Discover IoT Devices on IoT Brokers	Υ	N	(Y)	N	(Y)	N
Easy management graphic interface to list and test IoT entities	Υ	(Y)	(Y)	(Y)	(Y)	(Y)
Manage IoT Device Model and Device Data Type ownership and access grant	Y	Y	(Y)	Y	Y	Υ







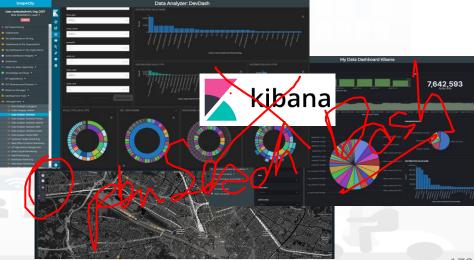


Two Main Lines for Dashboarding are present

• 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.







	•	_
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









	FIWARE ref arc smart city	Snar //Sitx
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: bidirectional
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.









Functional: FIWARE refarc. wrt Snap4City solutions

	FIWARE ref arc smart city	Snap4City	a
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.	6
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	60
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	M
Multitenacy on data management	No only on broker	Yes: on Broker, on data management, on dashboards, etc	60
Living Lab for creating/managing communities/groups	Not supported	Yes: provided in the open source	
Report generation/management	No	Yes	





DINFO DISTRIBUTIONS DISTRIBUTI



FIRENZE	ELL'INFORM	MAZIONE	TECHN	OLOGIES L	AB				<u> </u>										
	OT Discovery Abstraction	Authentication, Authorization	Security end-2-end, secure on OT and Dashboards	Open HW and Open SW	ntegrated Community nanagement	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	Dpen 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	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ
KAA [53]	Υ	Υ	Υ	Υ	Υ	Υ	N	Υ	Υ	Υ	Y	N	Υ	N	(Y)	N	N	Υ	Υ
Thingsboard [55]	Υ	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ	Υ	N	N	N	N	N	N	Υ	MQTT,coap, http
IOT eclipse.org [56]	N	N	N	(Y)	N	Υ	N	N	N	Υ	Υ	N	N	N	Υ	N	N	N	Υ
IOT IGNITE [57]	N	Υ	N	Υ	N	Υ	N	Υ	Υ	Υ	Υ	Υ	N	N	N	N	N	Υ	MQTT
FIWARE [47]	N	Υ	N	Υ	N	N	N	Υ	N	Υ	(Y)	(N)	Υ	N	Υ	N	N	Υ	Υ
ARM mbed IoT [48]	Υ	Υ	Υ	Υ	Υ	N	(N)	N	Υ	Υ	Υ	N	N	N	Υ	N	N	Υ	Limited
Airvantage [51]	Υ	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ	Υ	N	N	N	N	N	N	Υ	MQTT, HTTP
AWS [43]	Υ	Υ	Υ	Υ	N	Υ	(N)	Υ	Υ	N	Υ	N	N	N	Υ	Υ	(Y)	Υ	Limited
Azure IOT [44]	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ	N	Υ	N	N	N	Υ	Υ	(Y)	Υ	Limited
PTC ThingWorkx [59]	N	Υ	Υ	Υ	Υ	Υ	N	N	Υ	N	Υ	Υ	N	N	Υ	N	N	Υ	Υ
Bosch IoT Suite [58]	Υ	Υ	Υ	Υ	Υ	(Y)	(N)	Υ	Υ	N	Υ	Υ	Υ	N	Υ	N	Υ	Υ	Υ
CISCO Jasper [55]	Υ	Υ	Υ	Υ	N	(Y)	(N)	N	Υ	N	Υ	N	N	N	N		(Y)	Υ	N
Siemens MindSphere [60]	Υ	Υ	Υ	(Y)	N	Υ	(N)	Υ	Υ	N	Υ	Υ	N	N	Υ	N	Υ	Υ	Υ
Carriots [54]	Υ	Υ	Υ	(Y)	N	Υ	N	N	Υ	N	Υ	N	N	N		N	N	Υ	MQTT
Google IOT [45]	Υ	Υ	Υ	Υ	Υ	Υ	N	Υ	Υ	N	Υ	N	N	N	N	N	(Y)	(Y)	MQTT, HTTP
Homekit Apple [50]	Υ	Υ	Υ	Υ	N	Υ	N	N	Υ	N	(Y)	Ν	N	N	N	Υ	N	Υ	Limited
Smarthing Samsung [52]	Υ	Υ	Υ	Υ	Υ	Υ	(Y)	Υ	Υ	N	(Y)	N	N	N	N	N	N	Υ	Limited

Snap4City (C), October 2025









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
VirloT	Python	Docker, Kubernetes, Kafka	RESTful, NGSI Contenedores		Seleccionada para Evaluación
ITrade	Java, JavaScript	Kafka, Pulsar	RESTful	Contenedores	Pocos proyectos, enfocada en loT 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







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

From Operation to planning

https://www.snap4City.org

https://www.Km4City.org







Main Tasks





- 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**



Big picture and Long-term focused (2 to 5+ years)

Vision, Mission, Why, Policies and Direction

Executive-management

What is the right direction for the company?

- · Short-term focused (3 months to 2 years) **Tactical**
 - Focused on specific business department
 - Middle-management
 - · What activities to be planned in strategic alignment?



- · Focused on day-to-day running
- Detail level processes for specific outcomes
- Execution by teams and managers
- Are we acting in alignment with strategy?





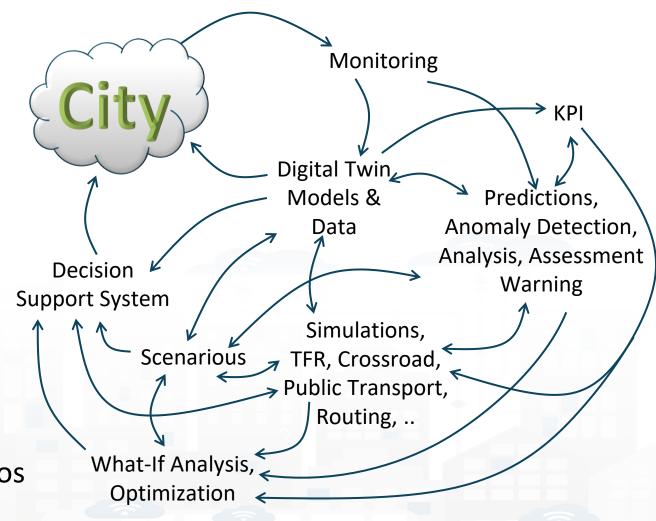




Main tasks



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

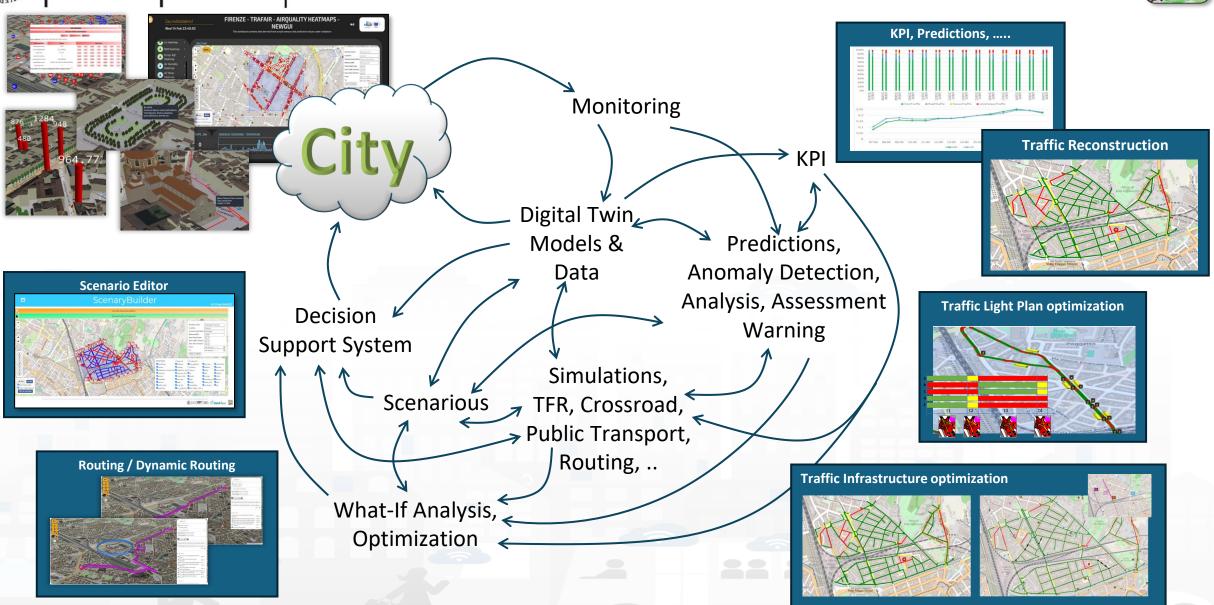












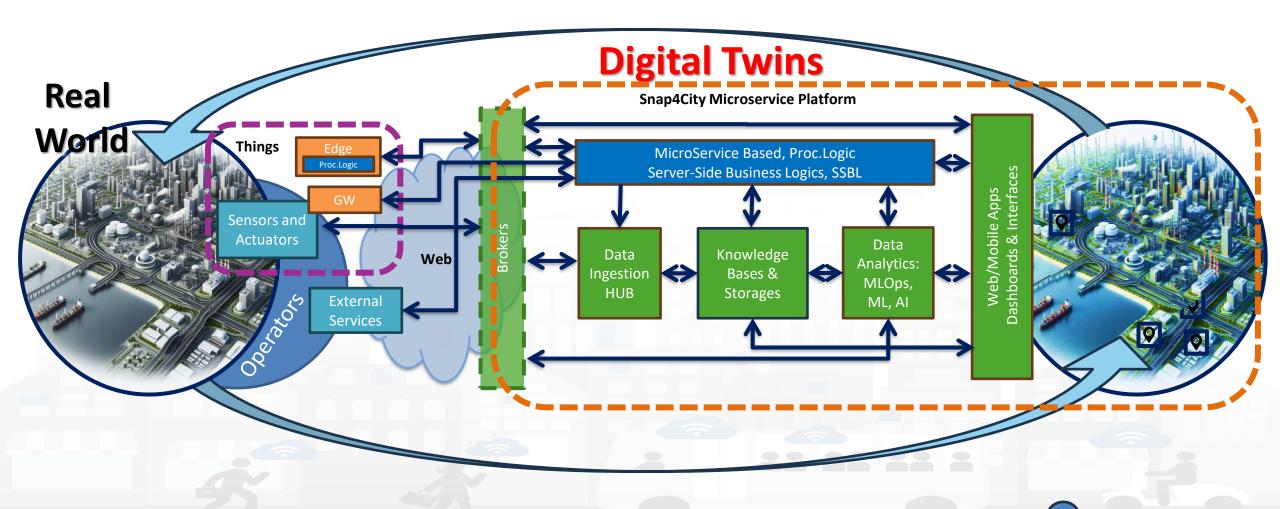








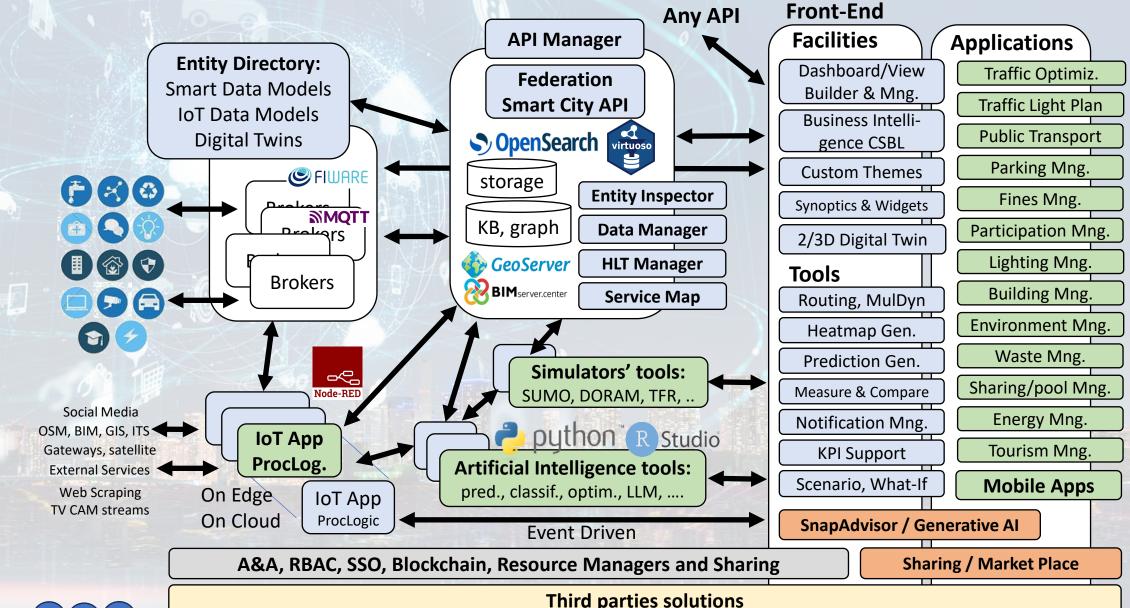
Digital Twin Development Platform



Technical Architecture







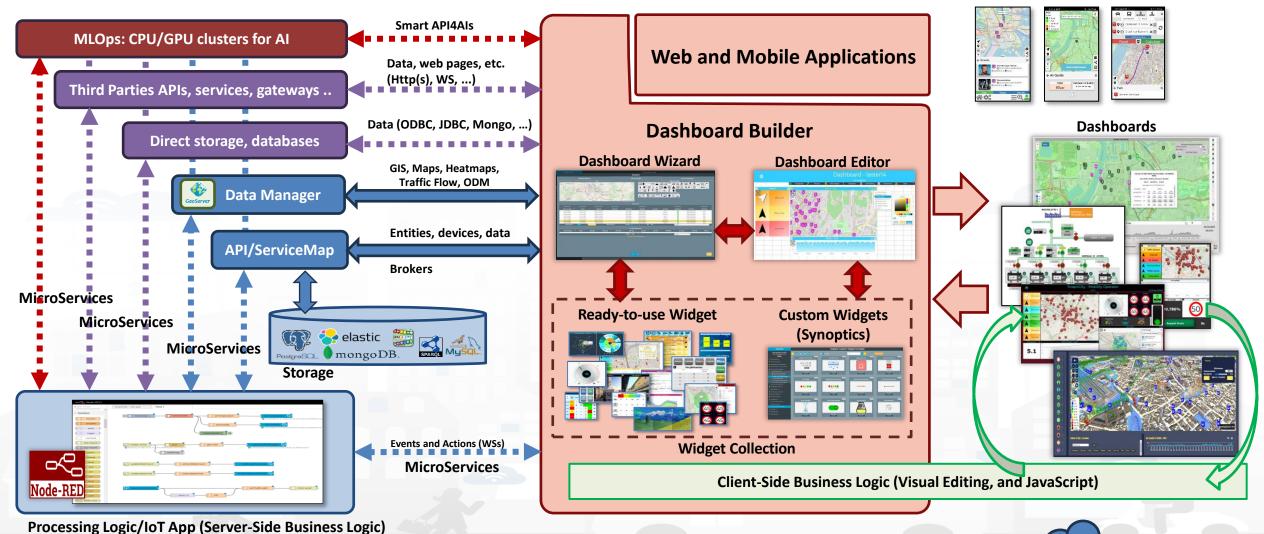








How the Dashboards / Apps Exchange data (2024/8)



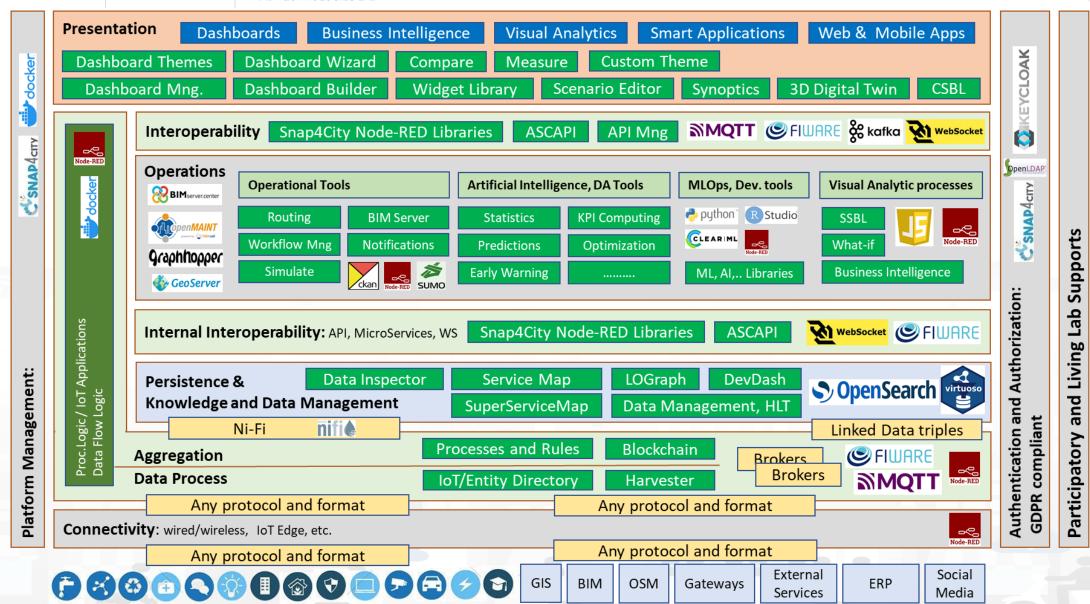




DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB













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

Development Life Cycle

https://www.snap4City.org

https://www.Km4City.org





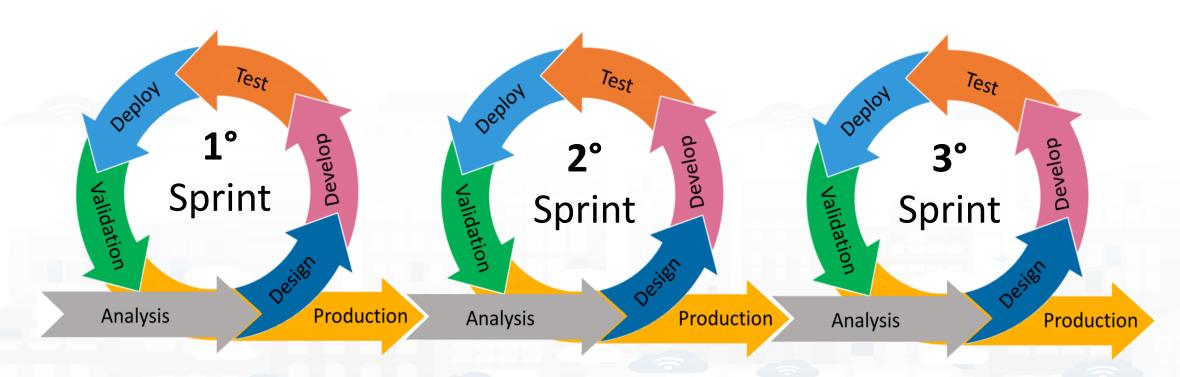






Development Life Cycle Smart Solutions





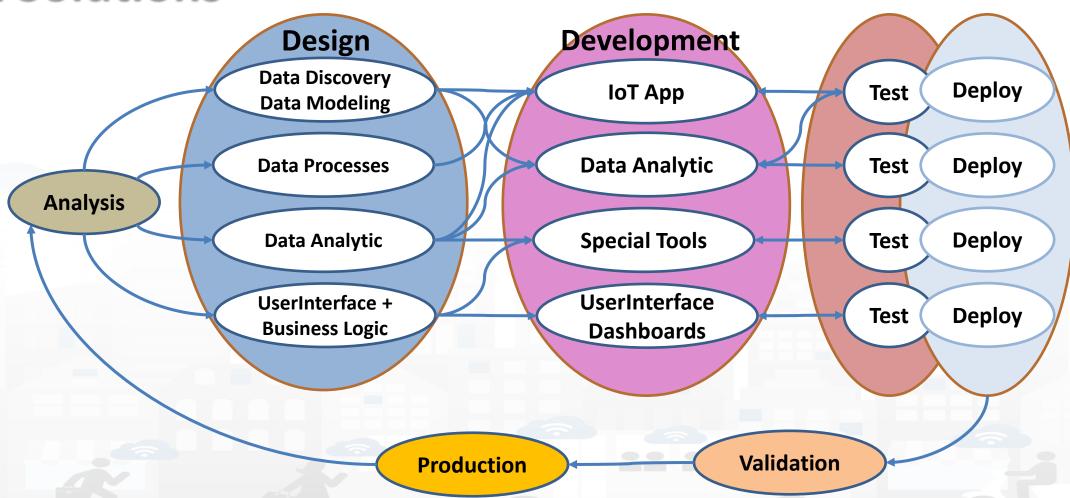








Development Life Cycle Smart Solutions





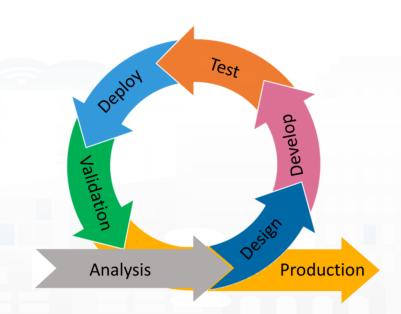


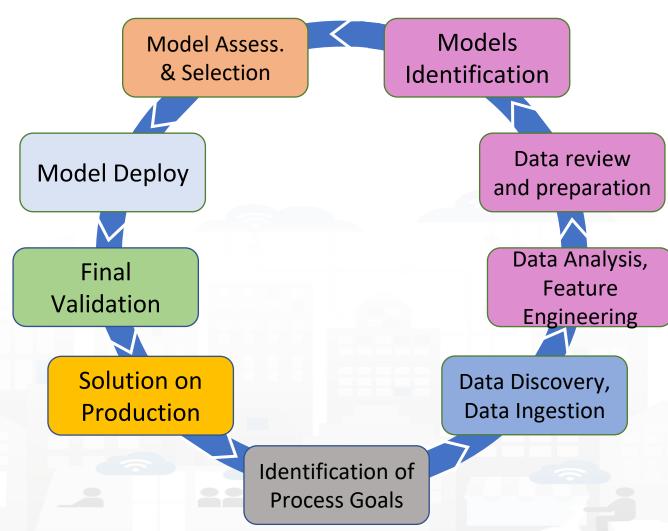




Data Analytics Development Life Cycle

 Detailed development process

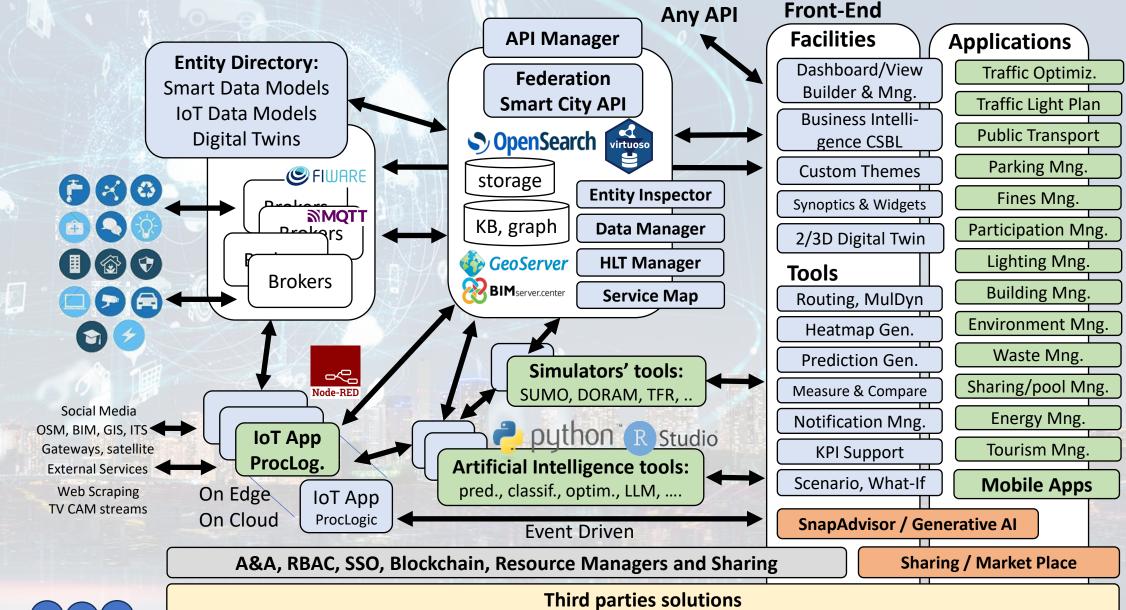


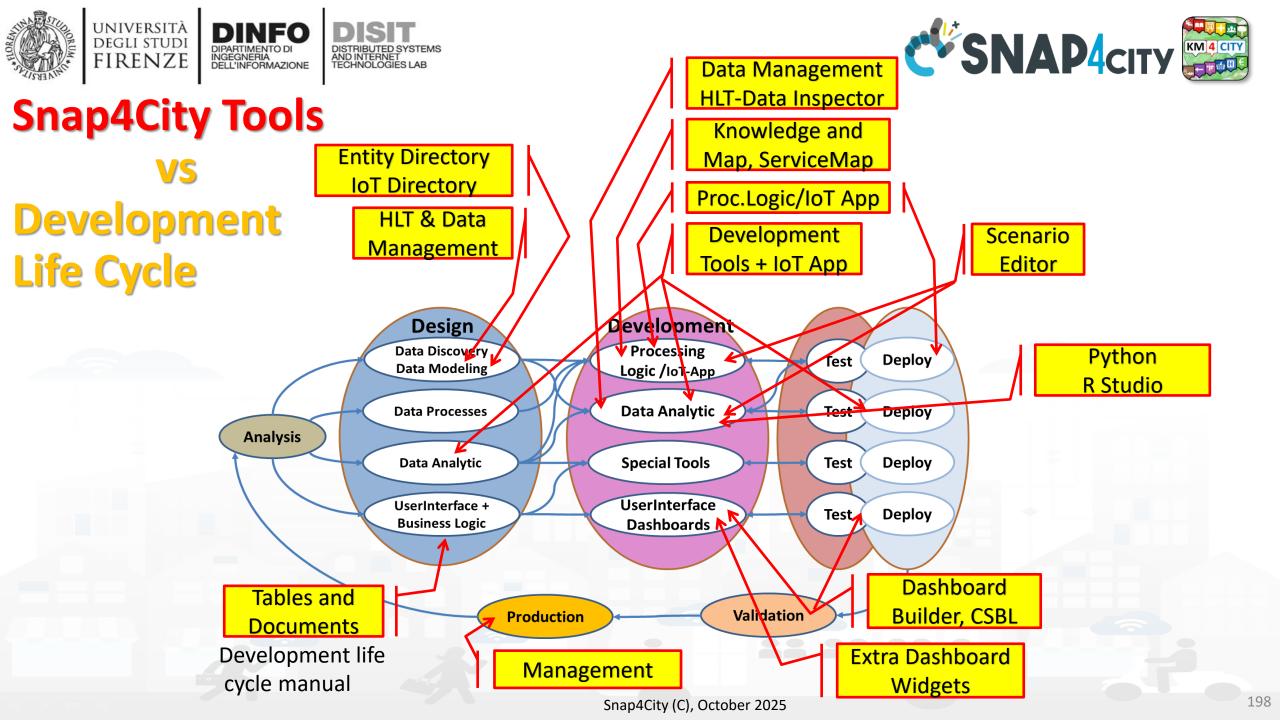


Technical Architecture









Visual Development Tools





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











Development

https://www.snap4city.org/d ownload/video/Snap4Tech-**Development-Life-Cycle.pdf**









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-
- https://www.snap4citv.org

- https://www.snap4industrv.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





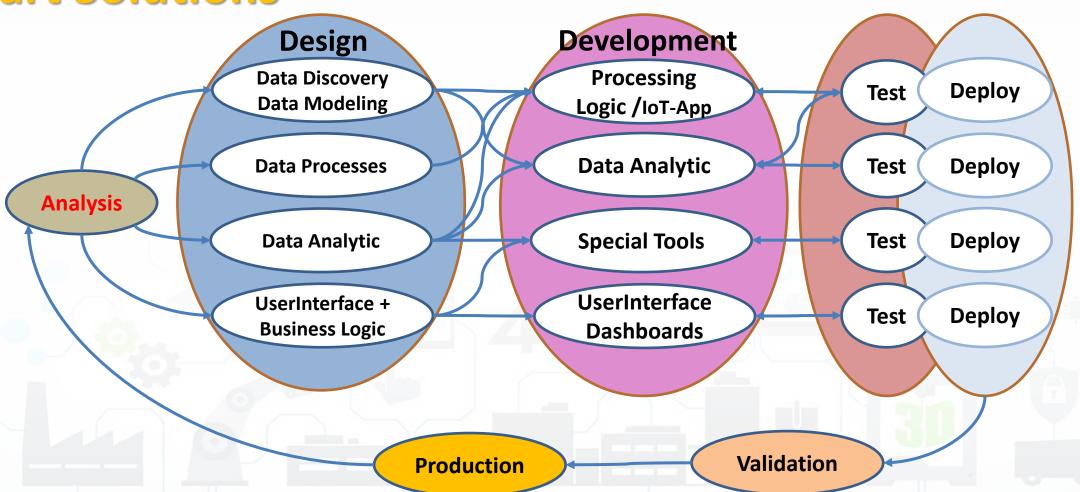








Development Life Cycle Smart Solutions







Analysis 1/2



- Performing workshops: Innovation Matrix by domain
- Entity Identification: which is the Dictionary
 - Actors and their profiles (as Entity Models, IoT Device Model): User, Operator, final user, ict expert, decision maker, doctors, driver, etc.
 - entities and their digital counterpart (as Entity Models, IoT Device Model) for: Vehicle, Analysis, Server, Client, Mobile App, parking area, etc.
 - Entity Instances / IoT Devices which are instances of the models as: City user XX, Control Room Operator, Doctor Rossi, Cop 3726, Car FI796HG, IoT Device XY, Trip 34, Patient Health Record for Robert, etc.
 - Modules or Tools of Third party or legacy tools: they are applications, servers, IoT Edge subsystems, well known services for data providing, gateway, brokers, etc., which should interact some how with your solutions. They can be on cloud or on some premise, they can provide you some External API, of some kind: WebServer, Rest Call, FTP, Web Socket, MQTT, etc.
 - External API: to interoperate with any other application and service / servers.
 - External Services / Web Pages: to host into the user interface and Dashboards elements coming from third party applications.
 - **Tools:** which can be actual software or hardware tools, and also data analytics, algorithms, procedures.















Snap4City (C), October 2025











The Dictionary of Entities

Dictionary of Entities						
Term	DataModel or Module	Kind Responsible		Status	Spec where	
Driver Healthiness	DriverHealthiness	Entity Model	Dr. Rick Ross	To be done	To be defined	
User profile A	DriverA	Entity Model				
Vehicle Event	VehicleEvent	Entity Model				
Remote Consolle	MyOperation	Application	J.T. Kirk	To be done	lost	
		IoT App				
		Dashboards				

Columns in green are expected to be filled in the design phase



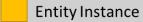


• For example: Let us now to suppose that we have to develop a solution for monitoring Vehicles and Drivers. Each Vehicle has a profile description and can be driven by a number of Drivers over time. Each Vehicle can experience some maintenance and performs trips in the city area. A trip has an official start/end and over time is described by its velocity, acceleration, brakes, charging level, or thank level, etc. Each Driver has a profile and can use a number of Vehicles to perform trips. During the trip also the Driver is monitored for its healthiness, attention, etc., and before, during and after the driving, periodically or sporadically may experience some Analysis to certify its capability to drive in that moment and for the next days. The Driver may experience some warning cases for healthiness, some tickets from policeman, some warning for high-speed velocity or generically bad driving, some problems from the vehicle's status, etc.





legenda





Entity Messages with dateObserved Register to instantiate -

Name: string

Surname: string

Data Model of the Driver

Age: number

Weight: number

Phone: string

Email: string

DriverAnalysisID: ServiceURI

Register to instantiate

Driver: user45

Name: David

Surname: Smith

Age: 45

Weight: 78 Kg

Phone: +49345096103

Email: david89@gmail.com

NikName: Carl

DriverAnalysis:

http://.../user45driveranalysis

Write SUR to create cross references

DriverAnalysis: user45driveranalysis

DriverID: http://.../user45

New Hoods dateObserved: 12-03-2022T12:00:00

Status: "none"

Location: null

Doctor: null

Tools: null

DriverAnalysis: user45driveranalysis DriverID: http://.../user45

dateObserved: 25-04-2022T12:00:00

Status: "bad"

Location: truck

Doctor: null

Tools: Eyetrack

New update on user45driveranalysis by sending almessage

DriverAnalysis: user45driveranalysis

DriverID: http://.../user45

dateObserved: 22-03-2022T12:00:00

Status: "good"

Location: room45

Doctor: https://....

Tools: null

userus on very one of the solution of the solu

Snap4City (C), October 2025

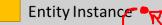








legenda







Register to instantiate _

MMI

Data Model of the Driver

- Name: string
- Surname: string
- Age: number
- Weight: number
- Phone: string
 - Email: string

DriverAnalysisID:

ServiceURI

Register to instantiate

Drivek: user45

- Name: David
- Surname: Smith
- Age: 45
- Weight: 78 Kg
- Phone: +49345096103
- Email: david89@gmail.com
- NikName: Carl /
- DriverAnalysis: http://.../user45driveranalysis

Write SUR to create cross references

DriverAnalysis: user45driveranalysis

- DriverID: http://.../user45
- New 1000 men dateObserved: 12-03-2022T12:00:00
- Status: "none"
- Location: null
- Doctor: null
- Tools: null

DriverAnalysis: user45driveranalysis

- DriverID: http://.../user45
- dateObserved: 25-04-2022T12:00:00
- Status: "bad"
- Location: truck
- Doctor: null
- Tools: Eyetrack

New update on user45driveranalysis by sending almessage

DriverAnalysis: user45driveranalysis

- DriverID: http://.../user45
- dateObserved: 22-03-2022T12:00:00
- Status: "good"
- Location: room45
- Doctor: https://....
- Tools: null

Separation of the separation o

Snap4City (C), October 2025









API, External Services

External API						
API	API url and	Kind	parameter	Credentials	status	Description, Swagger link,
name	shape			approach		Postman,
	GIS					
	CKAN					

Columns in green are expected to be filled in the design phase

External Services						
URL Web pages	parameter	Description	Nature	Subnature		

These info can be loaded on Snap4City platform to show them on dashboards easily



Analysis 2/2



- Scenarios describing the application/task, textual definition, with some standard table as UML. The scenarios have to refer to identified entities.
 - https://www.uml-diagrams.org/activity-diagrams-examples.html
- Use Cases describing the different cases into the single applications, by using UML formalization, there are specific Use Cases for each Scenario. Please focus on the most relevant, those that are adding value to your solutions. The others can be given for granted in a first phase.
- Requirements by using standard tables, using identified Dictionary of Entities, prioritizing them, setting mandatory/preferred/optional, functional and non-functional, first/second/third release, etc.
- Sequence Diagrams: for some of the critical aspects- For example for describing the user interaction, and/or the interaction among major entities, putting in evidence which is the Entity starting the dialogue with respect to the other Entities involved (e.g., a client requesting data to the server, a device sending data to the broker). UML sequence diagrams are a suitable formalization for the purpose.
 - https://en.wikipedia.org/wiki/Sequence_diagram

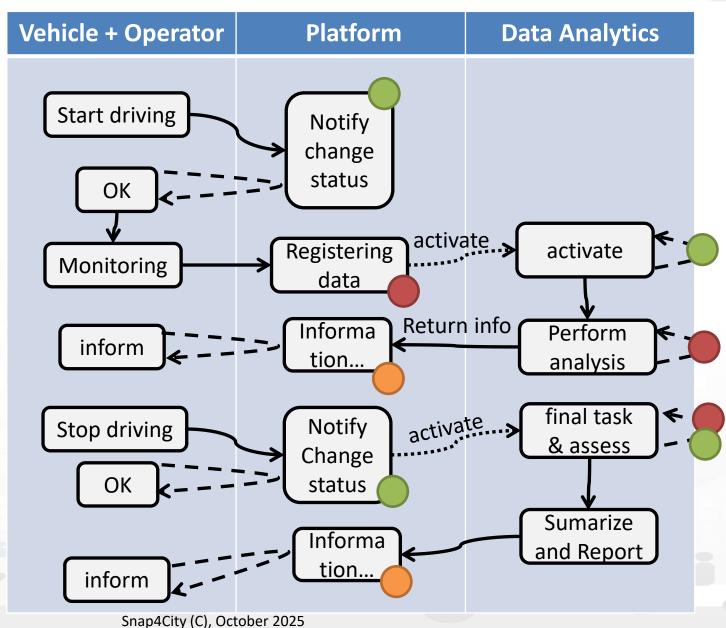




Example:

Activity Diagram

- Continuous Lines can denote event driven, sync communications... for example by sending data on IoT Broker
- Dashed lines can denote Pull data collected. Via Async. Communication from Platform to Mobile Devices, via SCAPI
- **Dotted line** can be even driven internal mechanism, internal call of API or other event drv.
- Coloured Dots are the different devices data storage





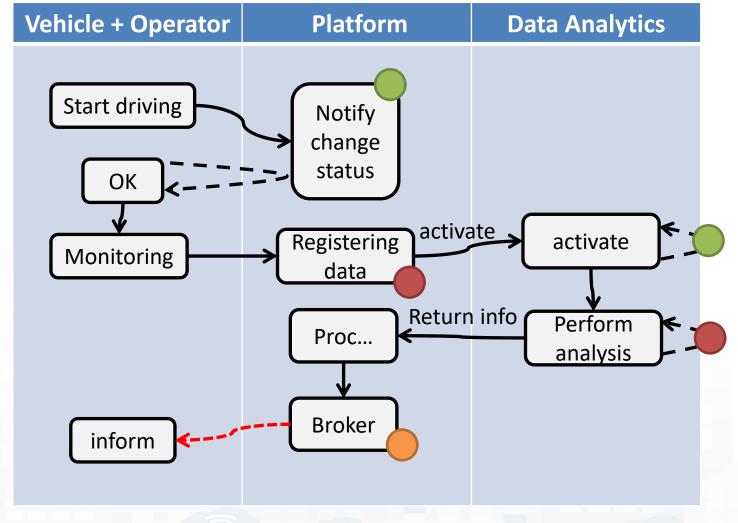




A variant



- Every time a data is entered into the Storage an event occurs into the broker
- The server «Inform»
 can be subscribed
 from an IoT App to
 receive in push these
 changes (red dashed
 line)



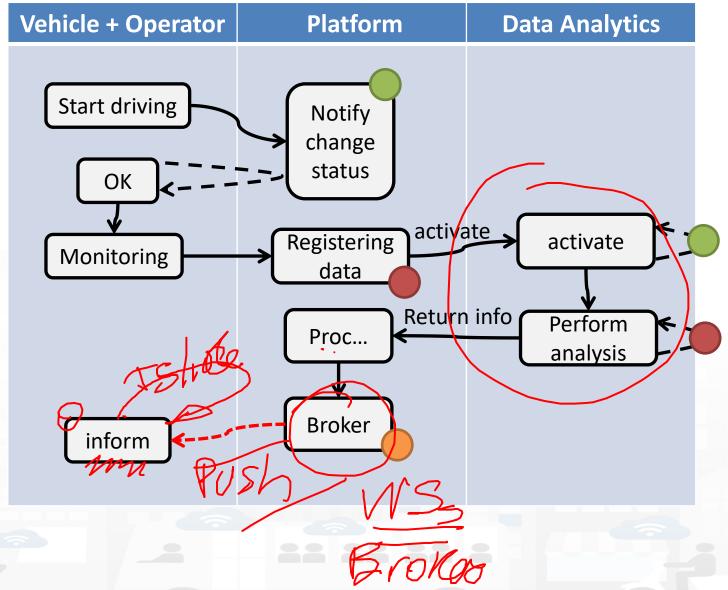




A variant



- Every time a data is entered into the Storage an event occurs into the broker
- The server «Inform»
 can be subscribed
 from an IoT App to
 receive in push these
 changes (red dashed
 line)











The above figure

- The driver on its Mobile App, he/she marks the start of the driving section, and the App notifies the change of status to the platform via some broker, once performed all the needed verifications (taking some minutes, may be).
- The effective change and authorization to start is made accessible by the platform to the mobile app which is requesting the status in pull (dashed line).
- Then the mobile app starts to monitor the drive status continuously, and send new data (e.g., the level of attention, the road taken, etc.) to the platform via some broker every minute.
- The arrival of new data may activate some data analytics to perform some analysis of the collected data (red dots) and producing results on the platform data. In the case in which the process detected critical conditions for the driver, the assessment procedure on platform may decide to send an event/message (dashed red, in push from platform to clients) to the operator and driver via a Broker to warning the driving of the lack of attention or for some wrong path.
- The event in push from platform to client could be a viable approach on some platforms and may have some limitation on Mobile App in which the interaction paradigm can be changed in a periodic REST call from the Mobile to the Platform.









	Requirements								
ID	Main Entity / Area	Description	Relevance / Priority	Main Tool-Module / Entity involved	Status	Source Code			
D1	Operator	The Operator has to be authorized to register Drivers	mandatory	OperatorTool	Not developed	JavaScript by xxxx on GitLab			
D2	Driver	The Drive can verify its registration by putting Password to access to its data on the solution	optional	Web and/or Mobile App accessible for the Drivers	accessible as open source	Yes In Java with AGPL licence			
	OperatorTool	Has to provide the list of pending assessment to be done							

Columns in green are expected to be filled in the design phase



Non Functional Requirements

Somehow related each other

- Protection, privacy, PENTest, GDPR compliance, ...
- Scalability, performance, efficiency, cloud/edge/container compliance
- Resilience, robustness
- Modularity, flexibility, reusability, maintainability, ...
- Portability, Openness, opensource
- Interoperability, standards compliance
- Responsive, usability, ...
- Etc.

All largely covered by Snap4City platform





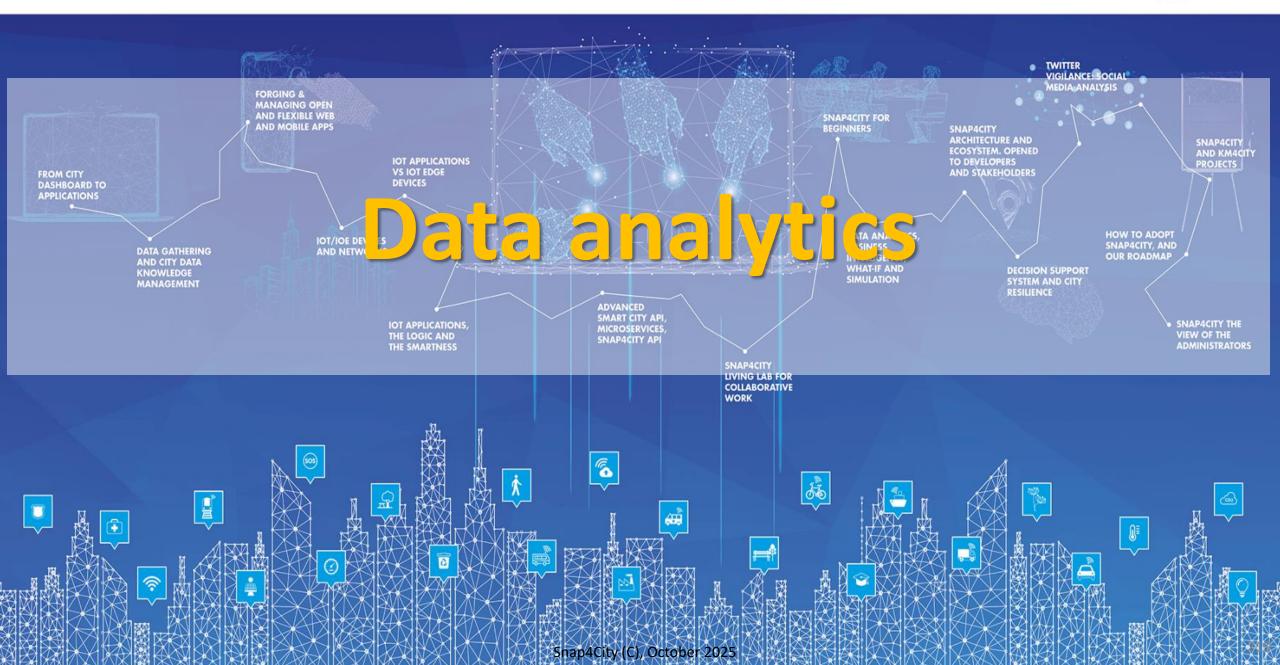




- Despite the Snap4City platform provides a full range of Non-Functional Requirements
 - You can with your analysis and design produce poor solutions
- For example, it is not a good approach to:
 - Collect user profiles and putting them public
 - Collect data every 10 second of phenomena which change only once a day
 - Couple your web/mobile applications with server-side processes by using synchronous communication in a context which is not synchronous and neither real time

SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES





Available AI Solutions on Snap4City

SNAP4city

https://www.snap4city.org/997

More than 80 Available Solutions & 300 Al 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/course/p4/





https://www.snap4city.o rg/download/video/DPL SNAP4SOLU.pdf

Snap4City (C), October 2025





Select map Zoom

Scenario name: Scenario name Location: Scenario description: Scenario description ReferenceKB: Reference KB Save Road Graph: Yes 🕶 Save traffic Sensors: Yes v Save other Sensors: Yes ∨ From: gg/mm/aaaa **Edit Road** gg/mm/aaaa --:--Show Summary | Cancel Segment Category Street: primary Nr.Lanes: Speed Limit (km/h): Direction: Positive direction Restrictions: Select or create restriction Update identifier + composition S elemLocation Select All Unselect All **☑**bridleway ☑bus_guideway☑bus_stop elementClass construction Corridor ✓ disused **⊠**elevator C elementType ✓emergency access point ✓emergency bay ✓ ✓ island ☑living street c length ✓ motorway **☑**platform ☑motorway link ☑no operatingStatus **primary** primary_link razed ✓ private speedLimit residential ☑rest area secondary linkservice View **e** Edit **I**tertiary services ✓ steps ☑ tertiary link ☑ track trafficDir Show Road graph tram ☑unclassified ☑via ferrata ✓ traffic island urunk link width Show Traffic Sensors ☑bus_guideway ☑ohm:military:Trench secondary highwayType Filter by road types route

New Scenario

Editing Drag & drop Split & Join Delete Do and Undo



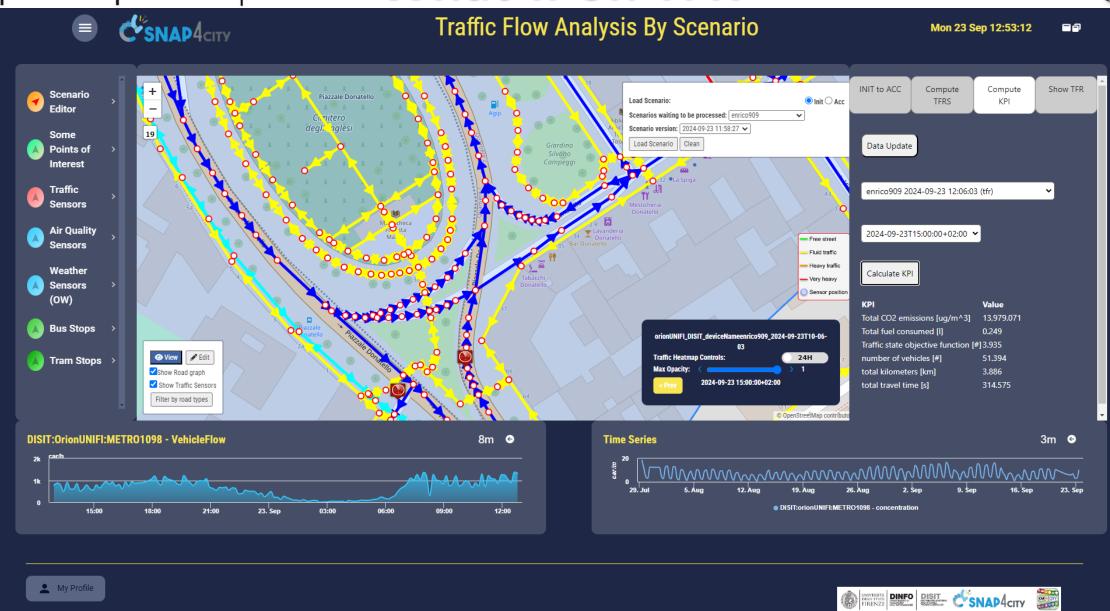
università degli studi FIRENZE

DINFO
DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

What-if on TFR







DINFO
DIPARTIMENTO DI
NGEGNERIA
DELL'INFORMAZIONE

DISTT
DISTRIBUTED SYSTEMS
AND INTERNET
TECHNOLOGIES LAB



223

Micro Simulation



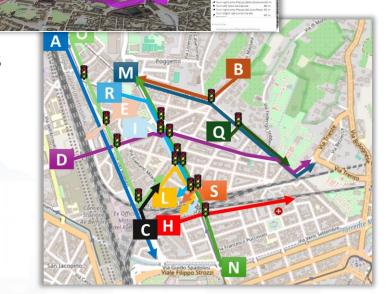








- Decongestion, Decarbonization, costs reductions
- Improve Accessibility to services
- Improve Security/Safety of city users
- Operation and Plan:
 - Traffic monitoring, prediction, reconstruction, identification of critical conditions (early warning), fleet management, dynamic routing, multimodal routing, 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, PQI, sat, etc.















Mobility and Transport Domain (2024/8)

- Goals:
 - Decongestion
 - Decarbonization
 - Accessibility to services
 - Security/Safety of city users
- Solutions for Operation (monitoring, managing, mobile apps, digital signages, control rooms)
 - Monitoring traffic, parking, people flow, services, boats, ports, beaches, etc.
 - Early detection/warning of critical conditions: traffic, congestion, security/safety
 - Managing Smart Parking, transportation services, fines, etc.
 - Managing fleets: personal, sharing, waste collection, maintenance, etc.
 - Managing E-sharing, pooling services, MaaS, etc.
 - Managing entrances in city areas: restricted areas, touristic busses, etc.
 - Production of suggestions, recommendations, nudging
 - Computing predictions of any kind
- Solutions for Planning (optimization and what-if analysis)
 - Reduction of traffic congestion, via optimization: traffic light plans, viability, routing
 - Reduction of Pollutant Emissions, via optimization: traffic light plans, viability
 - Optimization of transportation offers wrt multimodal mobility demand
- Algorithms and computational solutions, see next slide













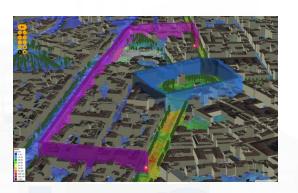


Tools for Mobility and Transport (2024/8)

- Optimisation of viability of an area for reducing congestion, waiting time, stops
- Optimisation of Traffic Light Plans, synchronization, in an area for reducing congestion, waiting time, stops
- **Predictions** for: traffic flow, smart parking, smart bike sharing, people flows, etc. (ML, DL)
- What if analysis: routing, traffic flow, demand vs offer, pollutant, etc. (Simulation + ML)
- Traffic flow reconstruction from sensors and other sources (simulation + ML)
- Public Transportation: Ingestion and modelling of GTFS, Transmodel, NeTEx, etc. (DP)
 - Analysis of the demand mobility vs offer transport of according to public transportation and multiple data sources (Simulation)
 - Assessing quality of public transportation (analysis)
- Accidents heatmaps, anomaly detection (analysis, ML)
- Road light controlled by traffic conditions
- Tracking fleets, people, via devices: OBU, OBD2, mobile apps, etc. (DP)
- Routing and multimodal routing (multistop travel planning), constrained routing, dynamic routing (DA)
- Computing Origin Destination Matrices from different kind of data (analysis, DP, DP)
- Computing typical trajectories on the basis of tracks (analysis, ML)
- Fleet management, monitoring, booking, allocation, maintenance
- Computing Messages for Connected drive (DP)
- Slow and Fast Mobility 15 Minute City Indexes (analysis, DP, ...ML)
- Computing and comparing traffic flow on devices and at the city border (analysis)
- Typical time trends for traffic flow and IoT Time series. (analysis, ML)
- Impact of COVID-19 on mobility and transport
- Computing SUMI, PUMS, etc. (mainly DP)
- Definition of Scenarios: traffic, road graph, conditions, etc.
- Etc.















Predictions and Heatmaps in Real Time



What-if Analysis on Pub Transport





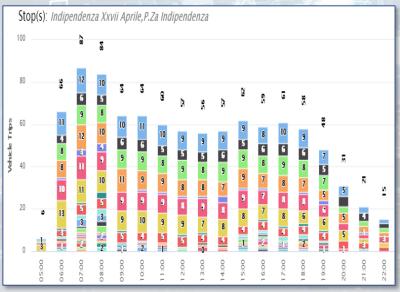


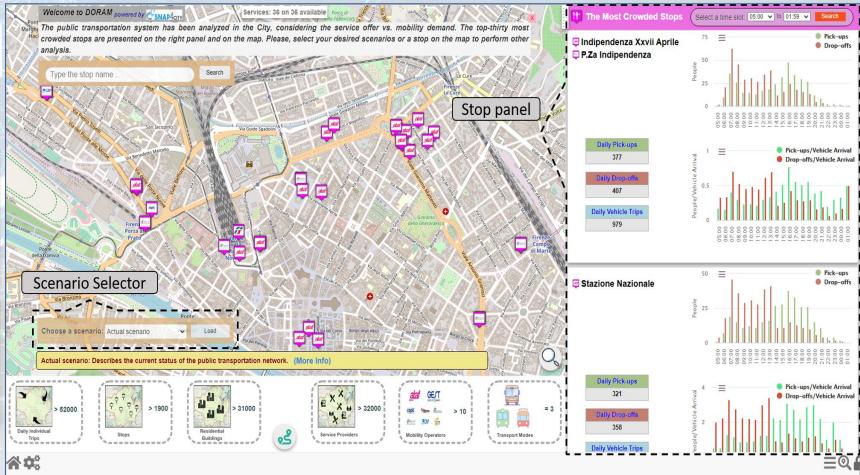




- Simulation / analysis of Demand and Offer of transportation
- Definition of scenarious impact on
 - Traffic, Pollutant, parking, public transport, private flows, etc.
 - KPI analysis

Public Services





Snap4City (C), October 2025

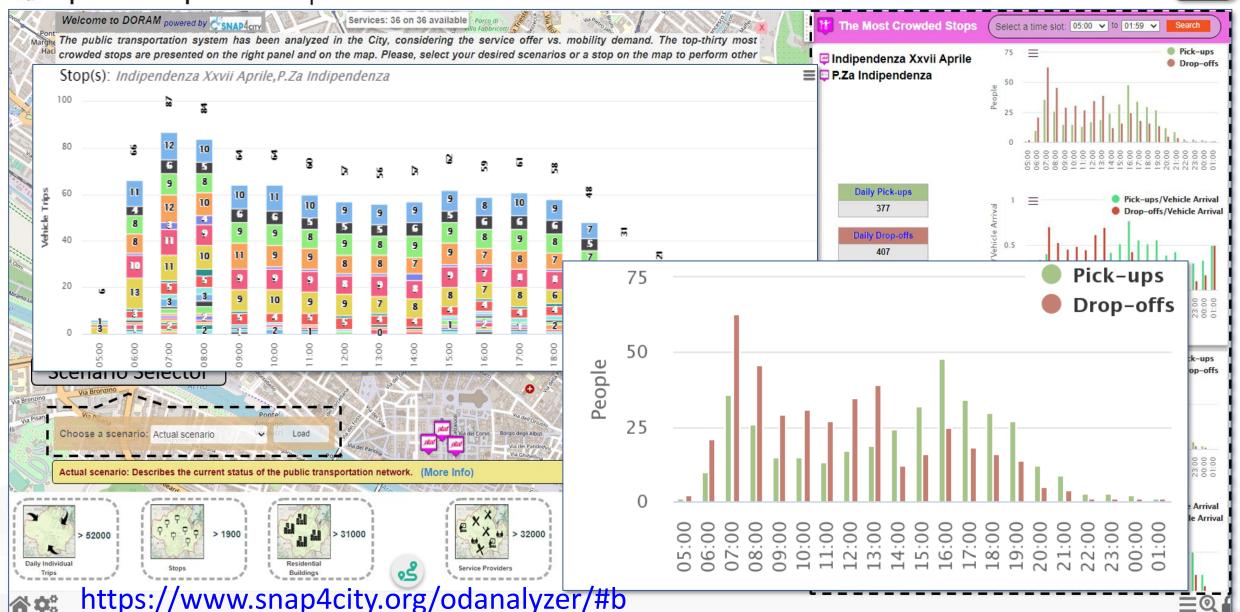


DINFO
DIPARTIMENTO DI
INGEGNERIA
DELL'INFORMAZIONE

DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB

DORAM









DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB





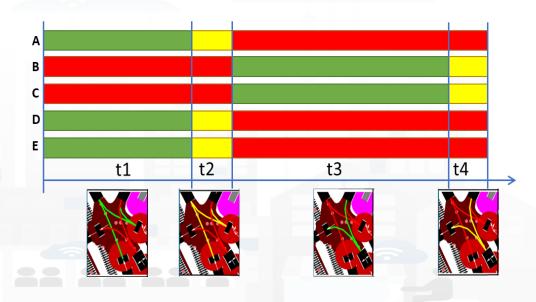




Traffic Light Plan Optimisation, Digital Twin

- Match Multiple Objectives and Synchronization:
 - public and private traffic, tramway priority
 - Micro and Macro Scales
 - Al: 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%



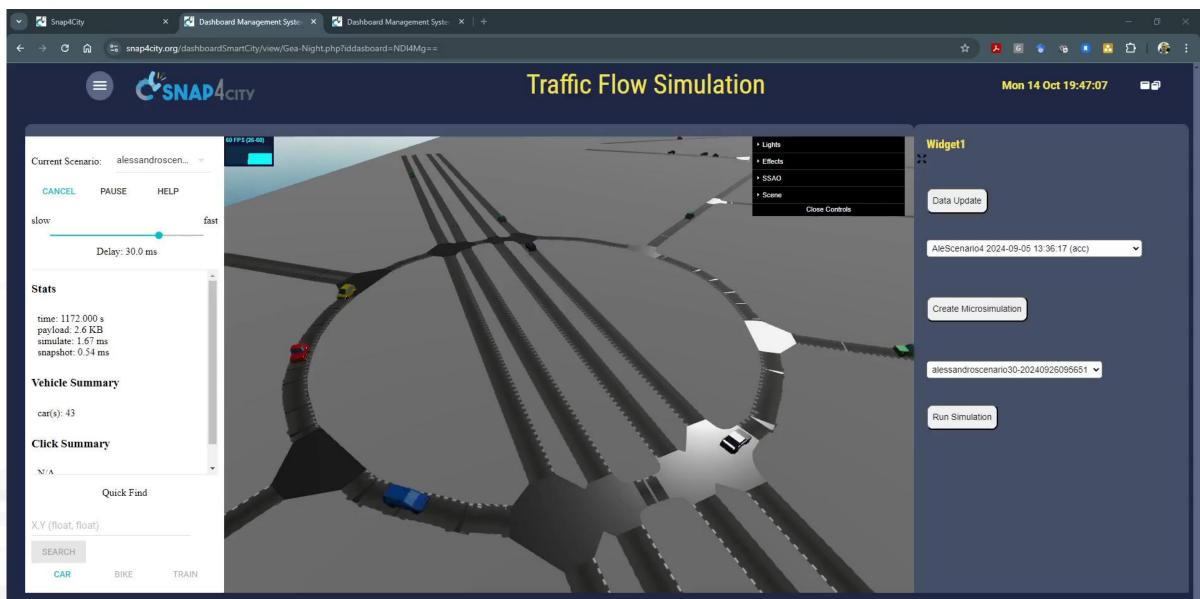




















Mean Travel Time

	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







VIEW OF THE **ADMINISTRATORS**

Traffic Infrastructure Optimization

















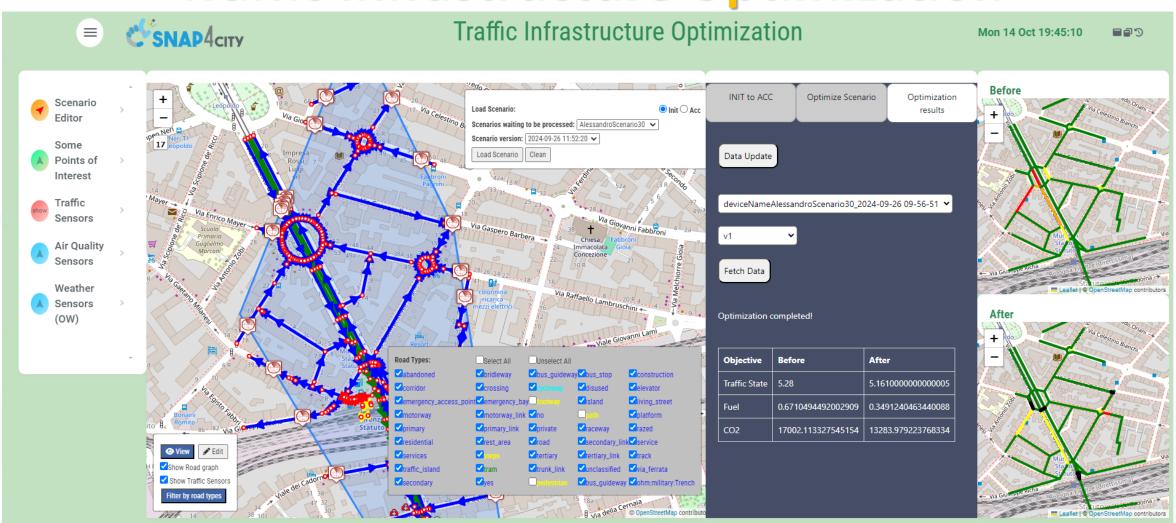








Traffic Infrastructure Optimization











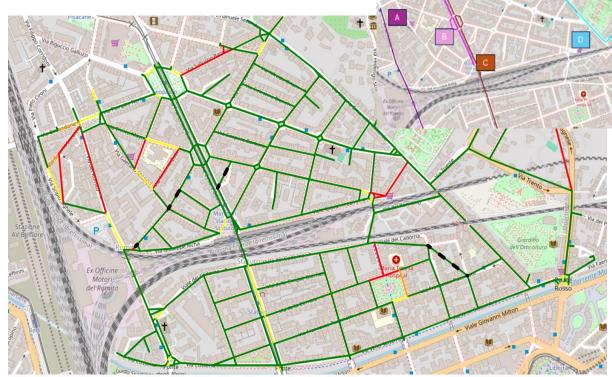




Optimization Results



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

-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, ...











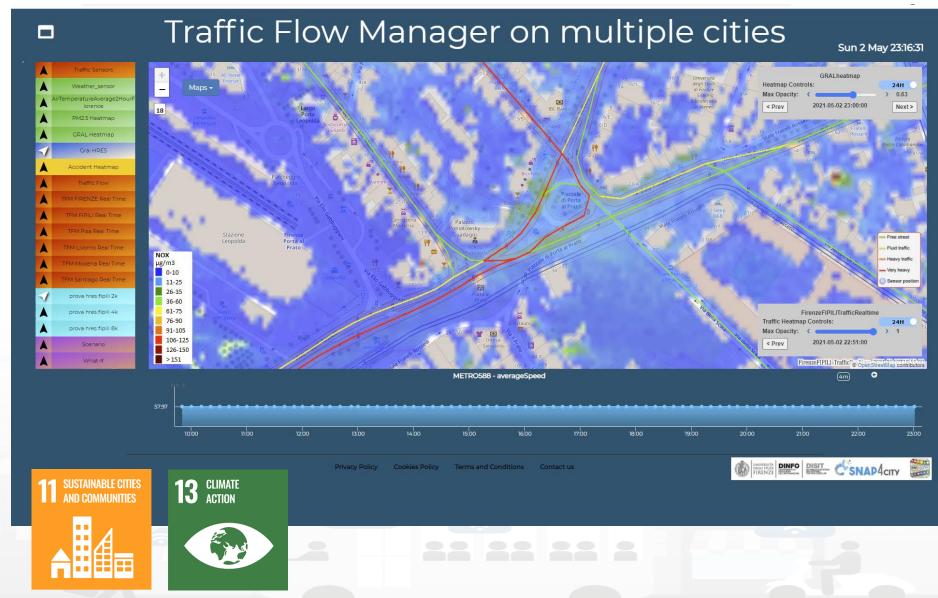


Prediction

- 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 Al











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 🤔

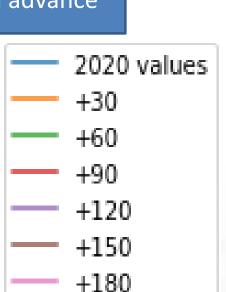
NoxDomestic

numberOfVehicles

NO2cumulated

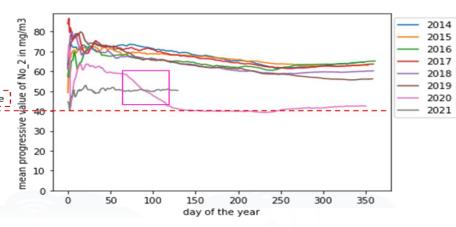
- NO2progresseveMean

numberOfVehiclesCumulated









		Air Quality Directive			WHOguidelines	
Pollutant	Averaging period	Objective and legal nature concentration	e and Comments	Concentration	Comments	
PM _{2.5}	One day			25 μg/m³ (*)	99 th 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 (*)	99 th 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



- 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





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)





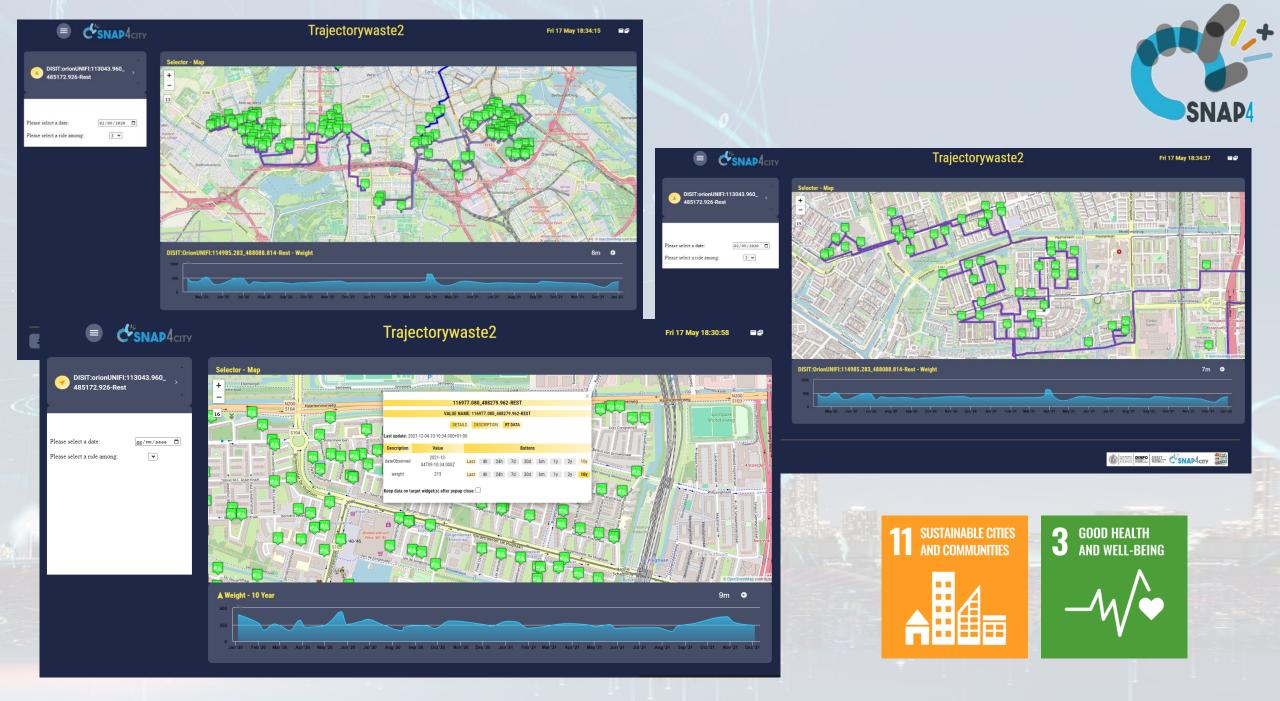












Snap4City (C), October 2025







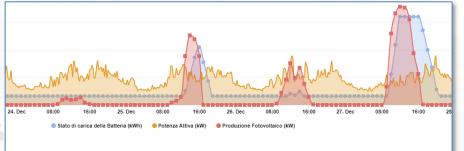
SNAP4city W4 CITY

Goals: City Energy and Buildings

- Energy consumption reduction, increment of efficiency,
- Areas and building sustainability
- Improve accessibility to services, security and safety
- Energy Monitoring: Building, floors, rooms, recharging poles, cabinets, Community of Energy, Data centers, Energy for Hot / cold, air condition, energy vs temperature and usage, etc.
- Energy Management: Predictions, early warning, identification of critical conditions
- Smart Light Management: LED/mixt, cabinets, lights vs traffic, lights vs security, energy saving, luminaries profiling, group management.
- Smart Building Management: consumption, number of people, etc.
 - Communities of Energy, Photovoltaic plants, sustainability
 - What-if analysis, optimisation tools
- KPI: Energy consumption, efficiency, pros/cons
 - Light profiling and adaptation
 - Autoclave industrial plants simulation, Photovoltaic plant simulation
 - consumption / usage, energy vs temperature
- Mobile App: monitoring, info-recharge, eSharing, booking, ...
- Participatory: problem reporting, ticketing, etc.
- Integration of any kind













ISPRA JRC Site











Floor Details



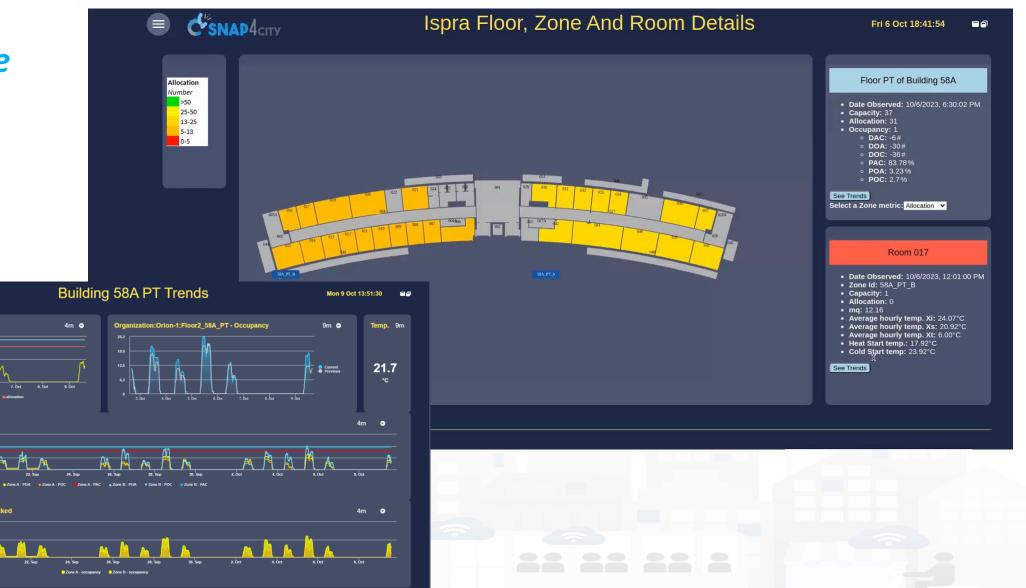
ISPRA JRC Site

C SNAP4CITY

Percentage Per Zones - Monthly Time Trend Comparison

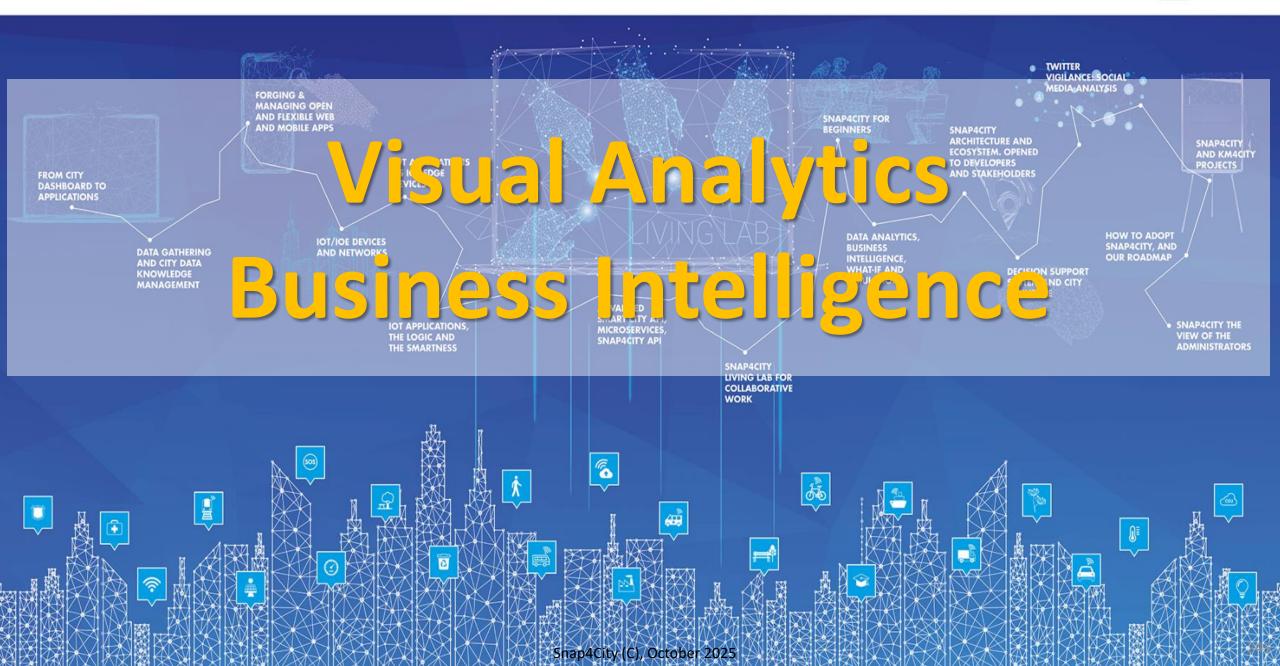
Occupancy Per Zones - Monthly Time Trend Comparison Stacked

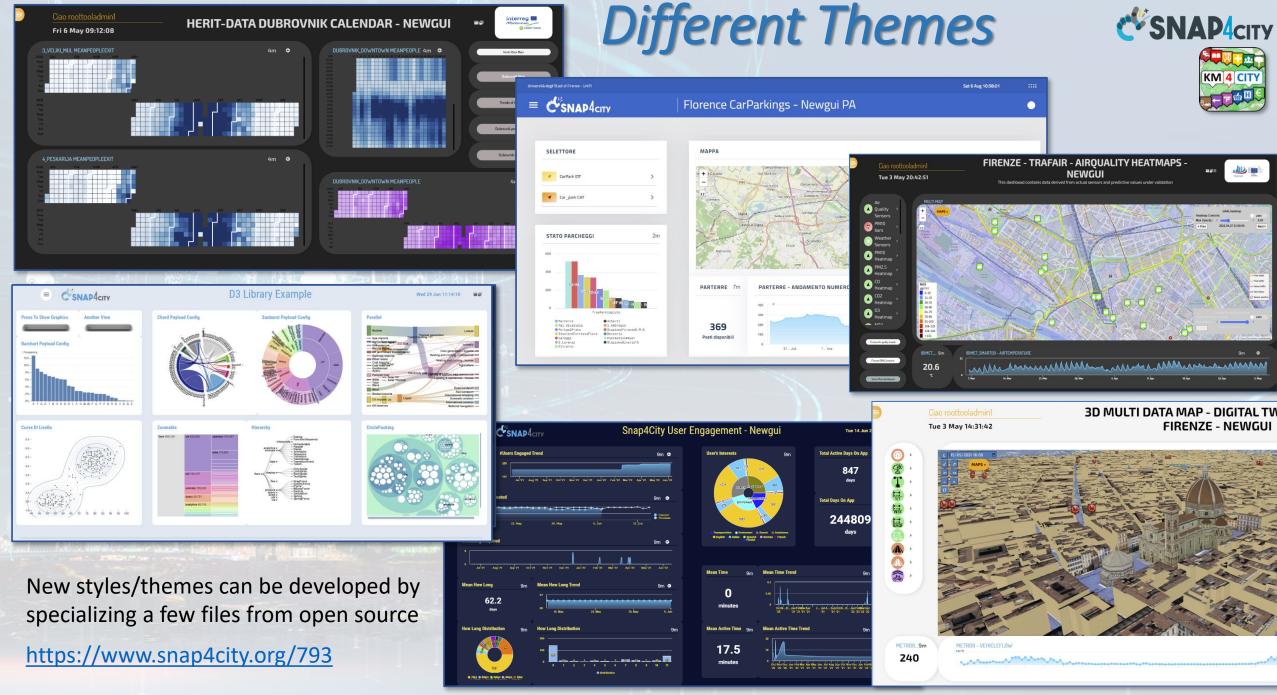
Capacity - Allocation - Occupancy



SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES







Snap4City (C), October 2025









Visual Representations



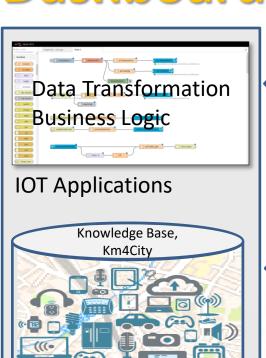






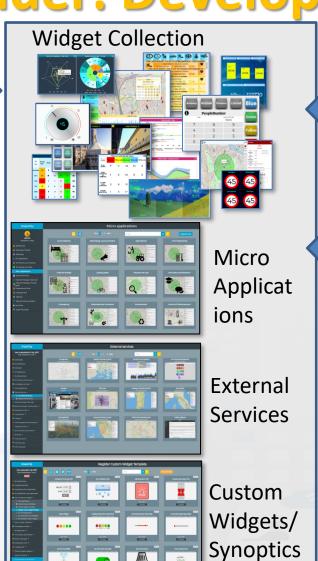


Dashboard Builder: Development



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









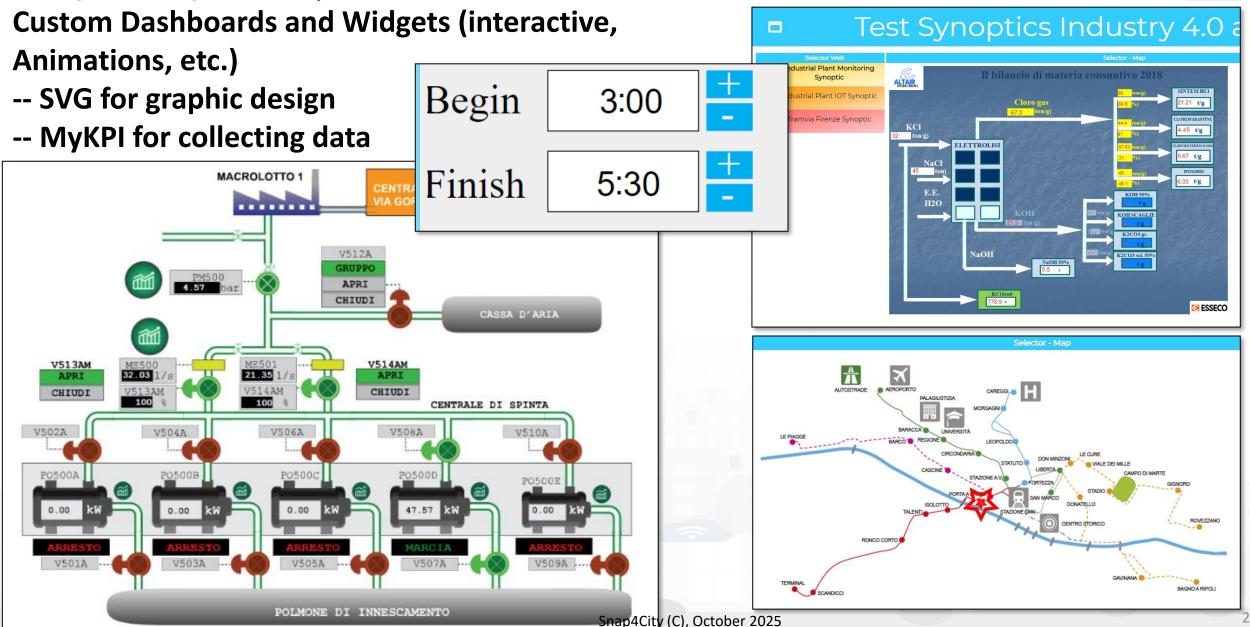




DISIT DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB CUSTOM Widgets















Special Custom Widgets



- Smart Energy
- Smart Light
- Smart

Begin

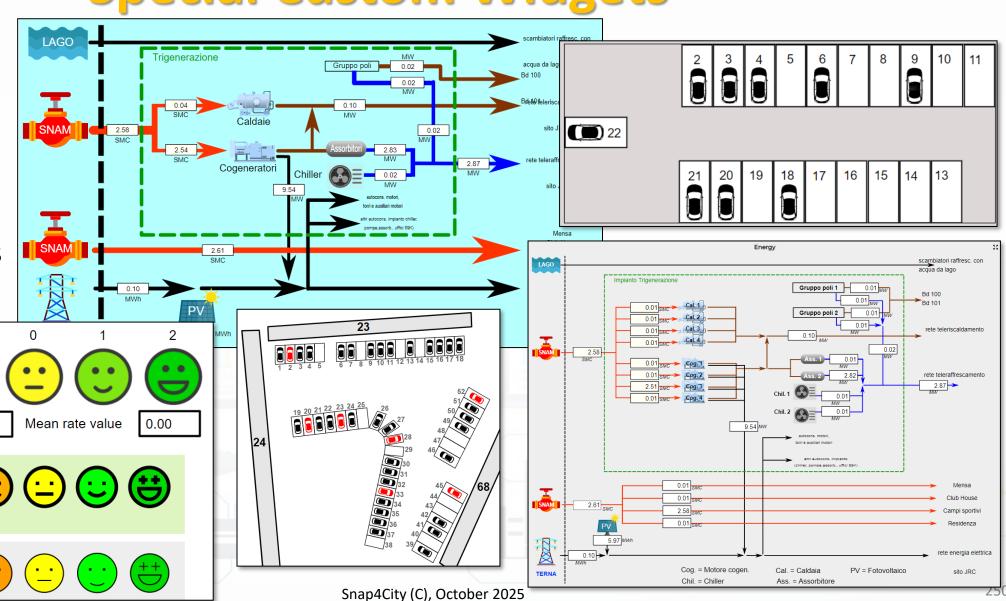
Finish

- Energy View
- Custom Controls

Total clicks

17:00

4:00



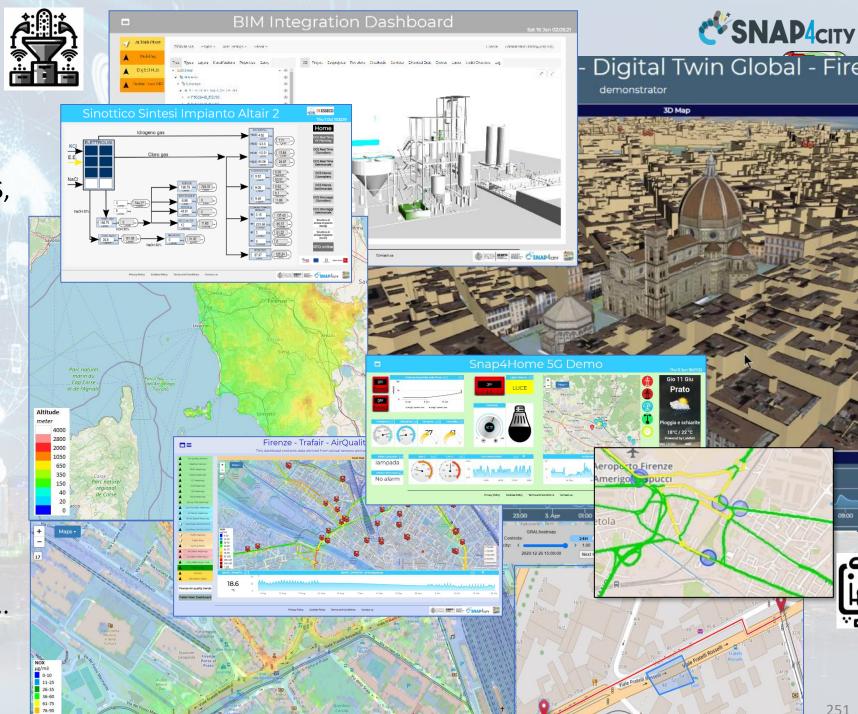
High Level Types

Snap4City (C), October 2025

- 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, ...









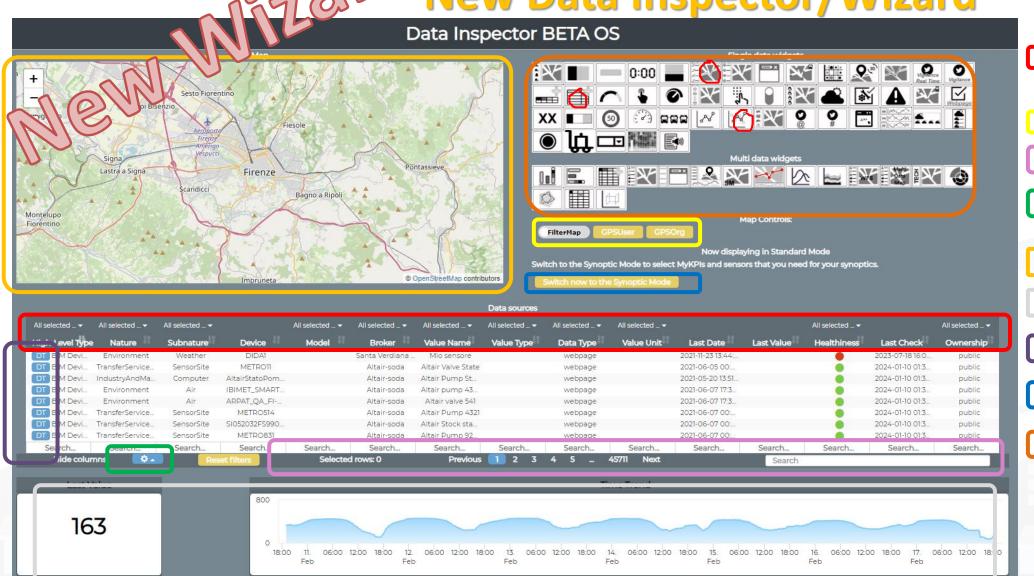
INGEGNERIA DELL'INFORMAZIONE







lew Data Inspector/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

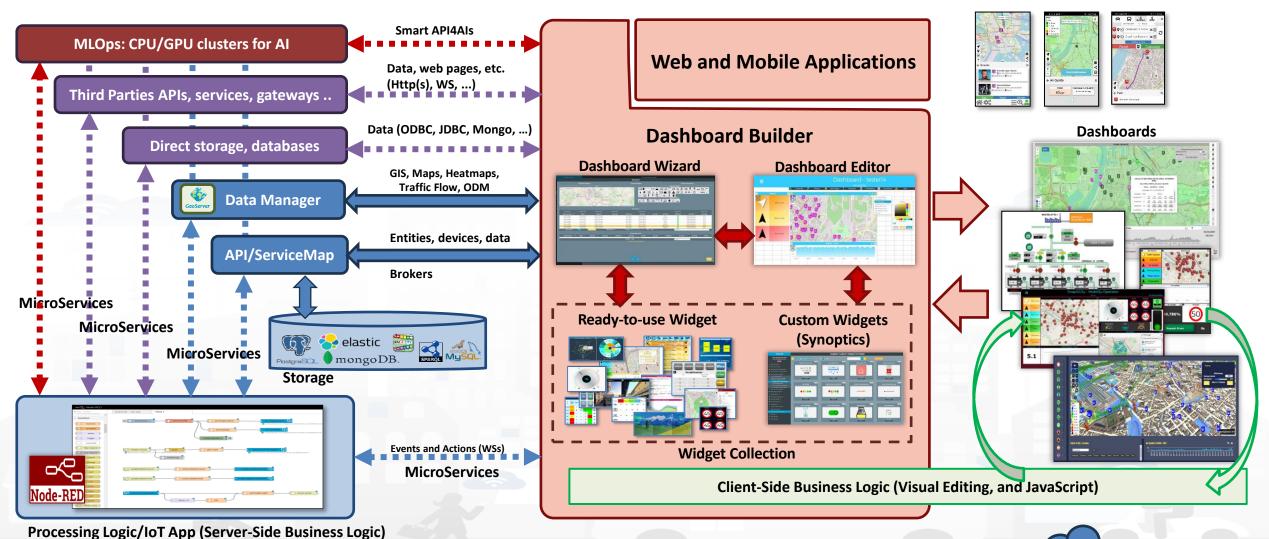
> Select the graph representation







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



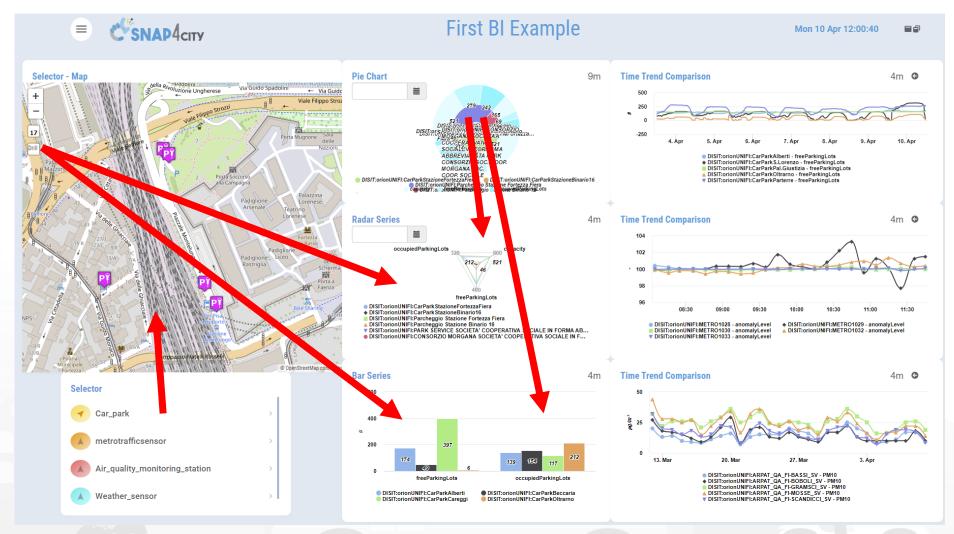






Example: From Map to Graphs (spatial drill down)

- 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



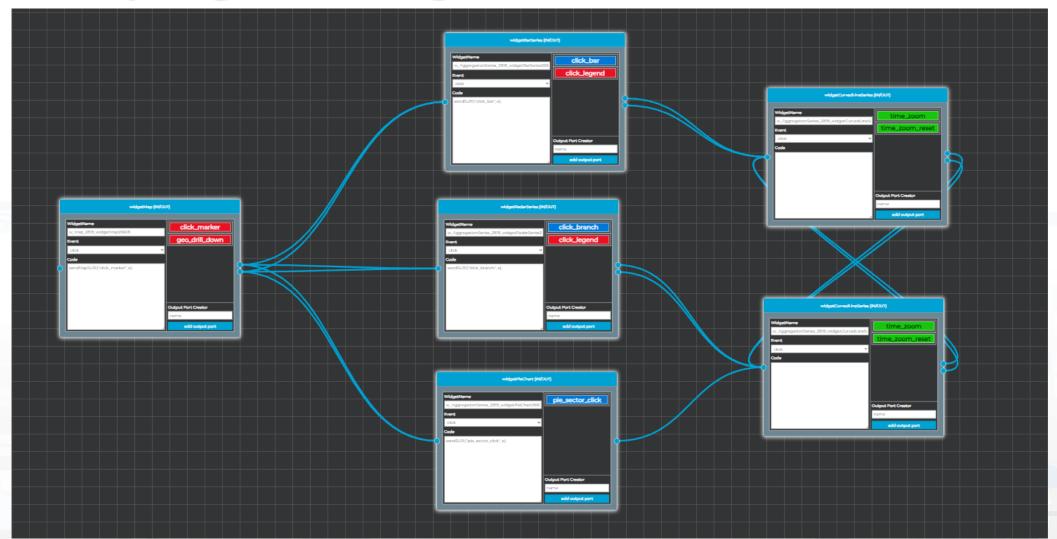








Visual programming for CSBL, accessible in beta























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-

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





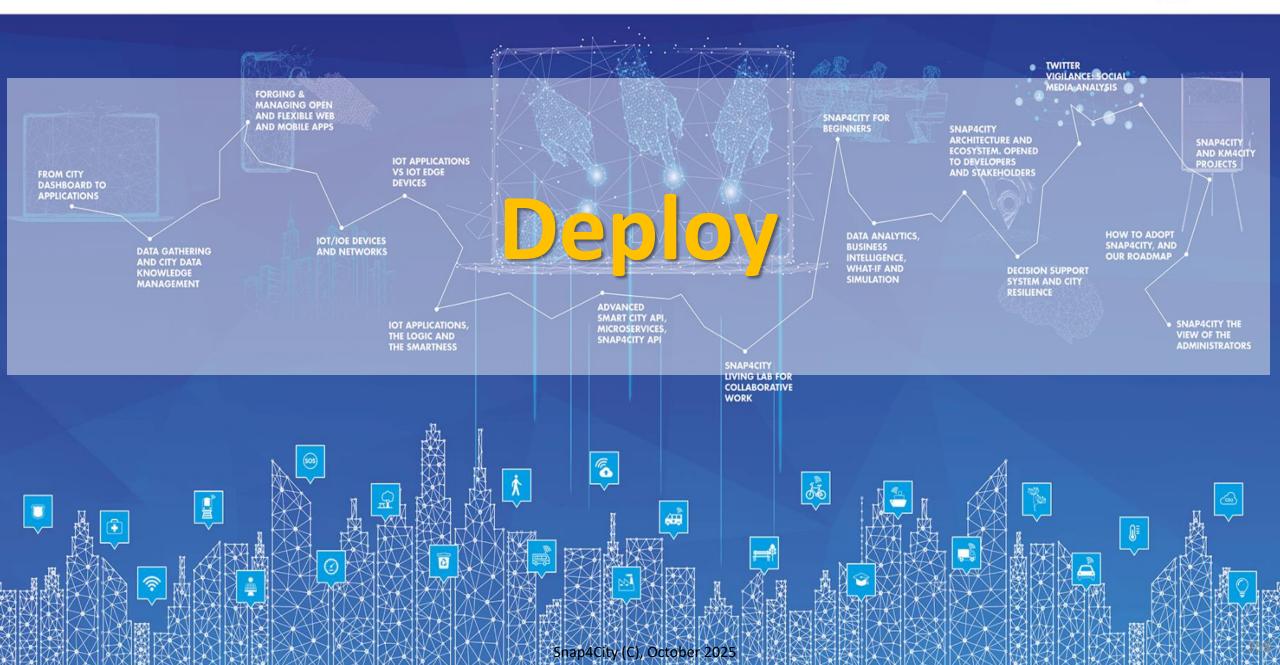


https://www.snap4city.org/do wnload/video/ClientSideBusin essLogic-WidgetManual.pdf



SCALABLE SMART ANALYTIC APPLICATION BUILDER FOR SENTIENT CITIES





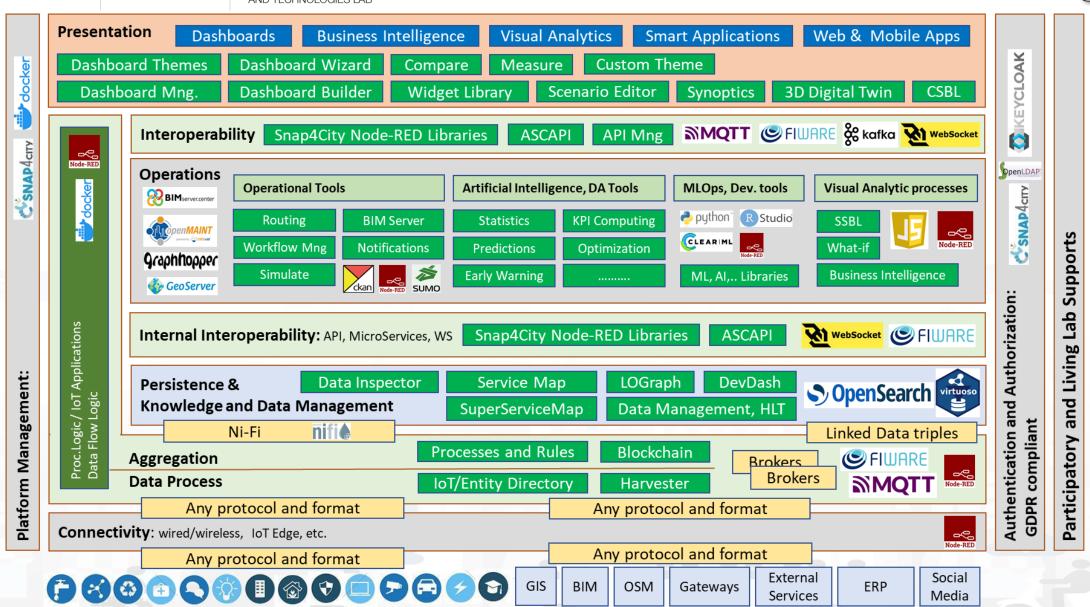




DISTRIBUTED SYSTEMS AND INTERNET TECHNOLOGIES LAB DISTRIBUTED DATA INTELLIGENCE AND TECHNOLOGIES LAB







Device Layer Snap4City (C), October 2025 **External Third Party Services**





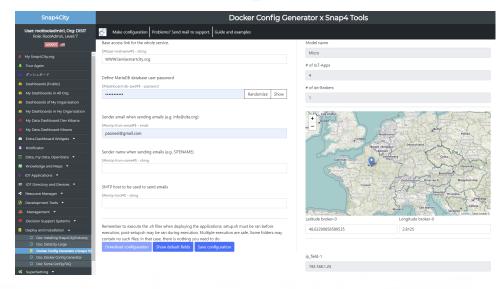


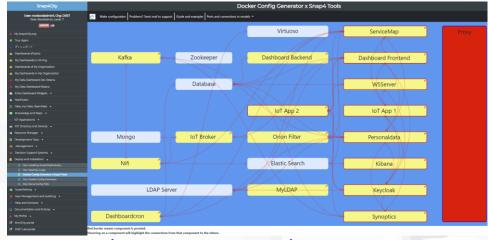


Installations, different models a TOOL to get them

- Micro X:
 - 1 VM of dockers
- Normal X,Y:
 - 2 VM of dockers
- Small X,Y: scalable
 - 4 VM of dockers
- DataCitySmall X,Y,Z: scalable
 - 6 VM of dockers
- DataCityMid X,Y,Z,T: scalable
 - # VM + X/70 VM + Y/3 VM + Z VM + T VM of dockers
- DataCityLarge: scalable
 - depending on your needs











Doc: Docker Config Generator Doc: Some Config FAQ

SuperSetting







Config Generator Tools

Snap4City	Docker Config Generator x Snap4 Tools				
User: roottooladmin1, Org: DISIT Role: RootAdmin, Level: 7	Make configuration Problems? Send mail to support. Guide and examples				
LOGOUT	Base access link for the whole service.	Model name			
My Snap4City.org	\$#base-hostname#\$ - string WWW.lamiasmartcity.org	Micro			
🜲 Tour Again	The state of the s	# of IoT-Apps			
🙉 ダッシュボード	Define MariaDB database user password	4	docker		
Dashboards (Public)	\$#dashboard-db-pwd#\$ - password	# of lot-Brokers	OOCKEI		
My Dashboards in All Org.	Randomize Show	1			
Dashboards of My Organization		1			
My Dashboards in My Organization		Isle of Man	Schleswigy		
My Data Dashboard Dev Kibana	Sender email when sending emails (e.g. info@site.org)	+ Dublin Groning	Hamburg Vojewodztwo Vojewodz		
My Data Dashboard Kibana	\$#smtp-from-email#\$ - email	re Cymru England Noord Holland	Niedersachsen Berlin		
Extra Dashboard Widgets ▼	paonesi@gmail.com	Vales Nederlands	Sachsen wolewoottwo Polska Anhali lubuskiiis wojewoottwo		
Notificator		België : Belgique	Deutschland Sachsen wiewodztwo opolskie swietokrzyskie		
■ Data, my Data, OpenData ▼	Sender name when sending emails (e.g. SITENAME)	Belgien Addesgey Letzebuerg	Česko Mojewodztwo Mai		
N Knowledge and Maps ▼	\$#smtp-from-name#\$ - string	Guernsey charlen charlen	Bayers Bayers Slovensko		
○ IOT Applications ▼		Bretagne Pays de Centre Val	Obrosterreich Sakaph Opfie Bratislava		
To IOT Directory and Devices ▼	SMTP host to be used to send emails	la Lore C de Loire Bourgogne for France Comte	Liechtenstein Österreich Liechtenstein Österreich Liechtenstein Österreich Magyarország Magyarország		
Resource Manager ▼	\$#smtp-host#\$ - string	Nouvelle Auvergne Valled	Suditol JAosta Combardia Veneto Slovenija Hrvatska		
d Development Tools ▼		Rhone-Alpes (e-Prie	lemonte Београд Београд Србица Emilia Romagna Србица		
Management ▼		Příříčípadou do Asturia	San Marino Sarajevo Leaflet Orion broker 0		
■ Decision Support Systems ▼		Latitude broker-0	Longitude broker-0		
Deploy and Installation ▲	Remember to execute the .sh files when deploying the applications; setup.sh must be ran before execution, post-setup.sh may be ran during execution. Multiple execution are safe. Some folders may	48.63290858589535	2.8125		
Doc: Installing Snap4City/Industry	contain no such files; in that case, there is nothing you need to do.				
Doc: DataCity-Large	Download configuration Show default fields Save configuration https://www.	ww.snap4city.org/docke	er-generator/selecting model		
Docker Config Generator x Snap4 To Doc: Docker Config Generator	inte post / / th	ip_field-1	. Actionately defecting influence		

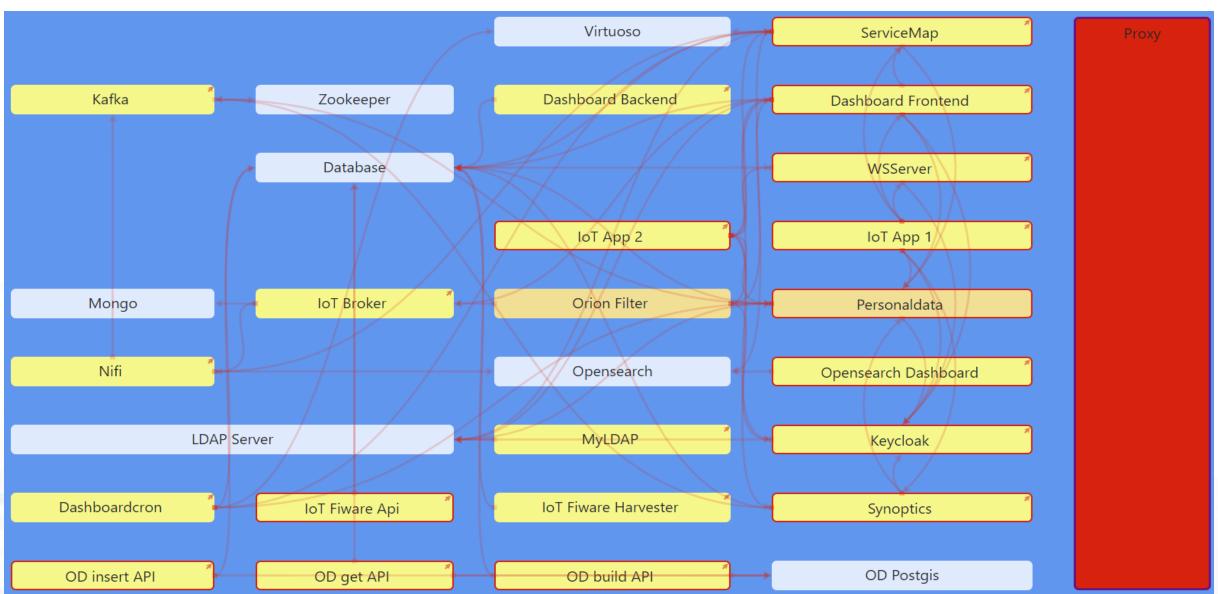
192.168.1.25









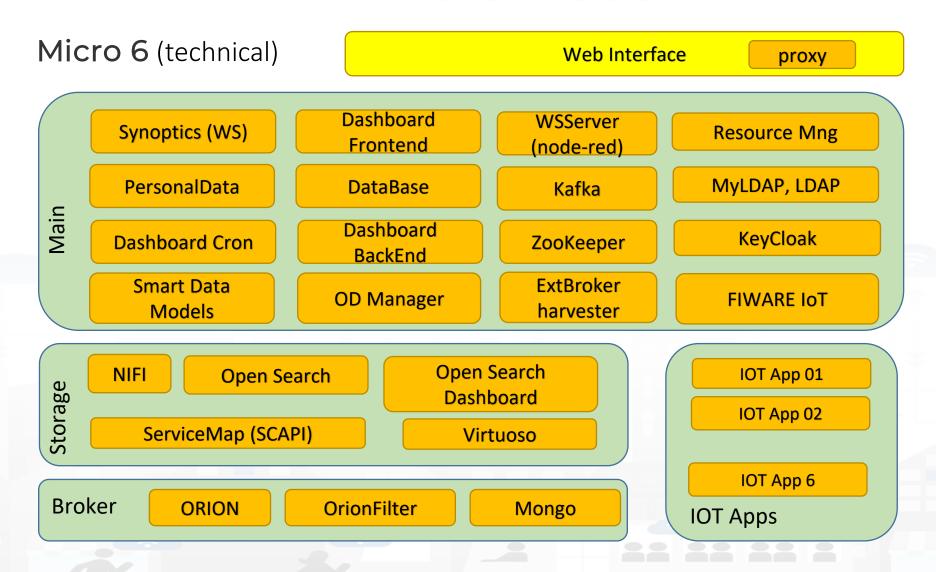






Micro 6 model









DataCitySmall X-2-2

Web Interfaces

