Enhancing Urban Living through AI and Hybrid Networks in Caltanissetta

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***Abstract*—In response to the growing demand for innovative solutions to enhance urban quality, the city of Caltanissetta has implemented a comprehensive initiative focused on the adoption of advanced technologies powered by Artificial Intelligence (AI). This initiative encompasses a range of research and development services aimed at improving environmental conditions, public health, and overall urban livability. In such a scenario, SmartMe has implemented a software ecosystem based on its Stack4Things framework and a LoRaWAN infrastructure to monitor weather conditions, air quality, park availability, and traffic flows throughout Caltanissetta. The ecosystem established in the city is an aggregation of Cyber-Physical Systems (CPS) spanning the urban area, with multiple co-existing appendices composed of specific CPS edge elements.**

Keywords—artificial intelligence, cyber-physical systems, internet of things, lorawan, smart city, smart mobility, smart parking

I. Introduction

Urban environments face a multitude of challenges, including pollution, traffic congestion, inefficient resource utilization, and inadequate public health monitoring. Addressing these issues requires an integrated approach that combines real-time data collection, advanced analytics, and responsive management systems. Recognizing this need, Caltanissetta has embarked on a path to become a smart city, utilizing Artificial Intelligence (AI) and Internet of Things (IoT) technologies to create a more sustainable and livable urban environment.

II. Case Study

In this Section we present and discuss the work carried out by SmartMe as part of the project named **"Servizi di ricerca e sviluppo funzionali all'adozione di sistemi di trasporto intelligenti per la città di Caltanissetta"** managed by a temporary joint venture composed by TIM S.p.A., Edisonweb s.r.l. and SmartMe.IO s.r.l. By leveraging cutting-edge technologies and data-driven approaches, the project aims to address pressing urban mobility challenges while fostering a more connected and responsive transportation ecosystem. More specifically, SmartMe has implemented a software ecosystem based on its Stack4Things [1] framework and a LoRaWAN infrastructure to cover the city of Caltanissetta in order to monitor weather conditions, air quality, park availability, and traffic flows.

Fig. 1. Environmental and traffic flow monitoring point in Caltanissetta.

The ecosystem created in the city of Caltanissetta is itself an agglomeration of CPSs [2] spanning the urban area, with multiple co-existing appendixes composed of specific CPS edge elements (Figure 1). The data gathered by the CPSs are transferred to the computation services through the exploitation of LoRaWAN, a wireless communication technology designed for IoT devices, which operates on sub-gigahertz frequency bands, offering long-range communication with low power consumption. SmartMe integrates LoRaWAN with LTE/4G modules and SIM cards in gateways, enhancing connectivity, redundancy, and reliability. The solution is able to solve several issues:

- **Enhanced connectivity:** While LoRaWAN offers long-range connectivity, it operates at lower data rates. Introducing 4G provides a high-speed connection, which can be particularly useful for transmitting large volumes of data or when real-time communication is necessary.
- **Redundancy and reliability:** Utilizing 4G as a backup or supplementary connection adds redundancy to the network. In case of LoRaWAN network issues or congestion, devices can seamlessly switch to the 4G connection, ensuring continuous data transmission and reliability.
- **Geographic coverage:** LoRaWAN networks might not comprehensively cover all areas, especially in remote or

challenging terrains. By incorporating 4G, IoT devices can maintain connectivity in regions where LoRaWAN coverage is limited or unavailable.

- **Firmware updates and remote management:** Leveraging 4G connectivity allows for efficient firmware updates and the remote management of IoT devices. These tasks often require higher bandwidth and lower latency, which 4G networks can provide more effectively than LoRaWAN.
- **Emergency situations:** Having a 4G fallback ensures reliable connectivity for critical data transmission.

III. SMART CITY DATASETS

Data collected from the city of Caltanissetta mainly consist in environmental data (DS1), data related to parking lots status that are derived from smart camera with on-board processing - no images recording - (DS2), and data related to vehicle flows in the main entrance roads of the city - anomalous traffic conditions are also detected – DS3.

Data are stored in Jason format and managed by Elastic search. It is specifically structured as follows:

- DS1 (10-minutes frame): temperature, pressure, wind direction, UV index, rain, PM1.0, PM2.5, PM10.
- DS2 (1-minute frame): N. of free parking slots
- DS3 (5-minutes frame): N. of cars, N. of motorbikes, N. of trucks, N. of persons, N. of buses, N. of bicycles, traffic anomalies

Figure 1 shows the monitoring dashboard of environmental data obtained from stations located in various points of the city of Caltanissetta. Along with data collected from devices monitoring pedestrian and vehicular flows, these insights are useful for improving city traffic, identifying areas of greater crowding, obtaining information on the frequency of visits to locations and commercial activities, and understanding whether tourist routes meet the needs of visitors or need to be reconsidered based on specific events.

Fig. 2. Monitoring dashboard of environmental data (DS1).

Figure 2 depicts a graphical representation of DS3, with color-coded source of traffic (e.g., cars, motorbikes, etc.). From the data, it is possible to derive and represent a series of traffic regularity indices, distinguished by area, type of source, etc.

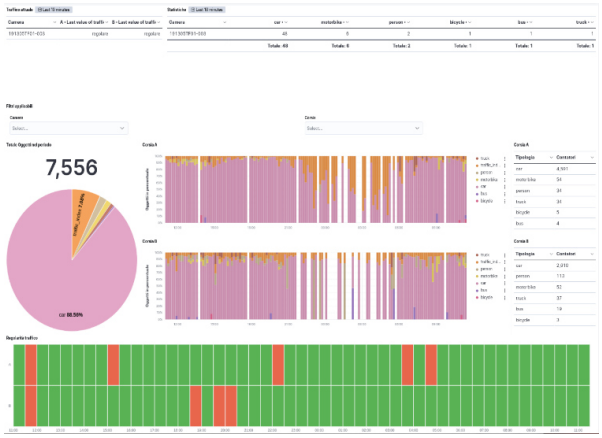

Fig. 3. Monitoring dashboard of pedestrian and vehicular flows (DS3).

IV. CONCLUSIONS

In this paper we presented and discussed the work carried out by SmartMe in the city of Caltanissetta. SmartMe has implemented a software ecosystem based on its Stack4Things framework and a LoRaWAN infrastructure to monitor weather conditions, air quality, park availability, and traffic flows throughout Caltanissetta. Advancements in edge computing platforms, microservices architectures, and cloud continuum approaches have revolutionized how computational tasks are distributed and executed within urban environments. By bringing computation closer to the data source and leveraging scalable, modular architectures, cities can efficiently deploy workflows, optimize resource utilization, and enhance overall system performance.

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