BARIUM5G – Blockchain and ARtificial Intelligence for Ubiquitous coMputing via 5G

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***Abstract*—The *BARIUM5G* project aims to define and propose innovative, sustainable and replicable hardware and software solutions on a large scale for the following Smart City scenarios: (a) efficient management of public lighting; (b) blockchain-based analysis and certification of vehicle fleet data; (c) blockchain-based supply chain traceability; (d) last-mile logistics based on Artificial Intelligence (AI) and Augmented Reality (AR). The fifth-generation (5G) mobile network will be leveraged across the board to enable the exploitation of emerging technologies such as Blockchain and Explainable Artificial Intelligence algorithms for deductive reasoning and data analysis. Research focus is placed on solutions that are easy to replicate, based on off-the-shelf devices and on the evolution of currently available frameworks. This will foster technology transfer results already in the short/medium term to make the best use of the 5G resources and infrastructures.**

I. Introduction

In 2017-2019, the Italian Ministry for Economic Development (MISE) funded experimentation of fifth-generation (5G) mobile telecommunications infrastructures in several Italian cities. The Information Systems Laboratory (SisInfLab) of the Polytechnic University of Bari took part in the Bari-Matera 5G use cases with TIM, Fastweb telcos and Huawei network equipment manufacturer. In 2020 the 2-year *BARIUM5G (Blockchain and ARtificial Intelligence for Ubiquitous coMputing via 5G)* project has started as an ideal follow-up, involving the study and definition of innovative techniques for unpredictable and opportunistic Smart City scenarios which can fully exploit the advantages introduced by 5G technology in terms of decreased latency and energy consumption as well as increased bandwidth, link stability and device density. The project encompasses four reference use cases in the Bari area, leveraging the 5G network across the board to enhance emerging technologies such as Blockchain and Explainable Artificial Intelligence for data analysis. The BARIUM5G vision is based on an approach seeing automated reasoning in the Internet of Things (IoT) [1]. It is known as Semantic Web of Things (SWoT) and is an innovative paradigm in the Information and Communication Technology (ICT) sector that aims to integrate Semantic Web and IoT. In this context, the experiences and results obtained in recent years by the SisInfLab research group, lead partner of the project, will be used as a starting point. Other partners are the Physics Department of the University of Bari, TIM and Idea75 innovative small-medium enterprise.

The project pays attention to the analysis and testing of innovative application methods and protocols for mobile scenarios based on the 5G infrastructure, in which smart devices connected to the network are able to communicate, share information and interact autonomously. The main objective is the definition of novel applications and services based on algorithms for automated reasoning, equipped with explicit and formal explanation capabilities of results, which allow to achieve high efficiency, reliability and quality of service in the reference scenarios.

The remainder of the paper is as follows: Section II outlines the four reference use cases of the BARIUM5G project, while conclusion sketches the prospected impact of the project.

II. Reference use cases

This section explores the four reference use cases which represent the pillars of the scientific and technical activity of the BARIUM5G project.

A. Efficient management of public lighting systems. The advantages introduced by the 5G network infrastructure, in terms of increased bandwidth and lower latency, are exploited to define a management system for public lighting which improves the quality of services offered to citizens. In particular, through the use of an *urban sensor network* of Smart Lighting devices, it will be possible to control the operation of the individual elements of the public lighting system as well as to identify and prevent outages. Semantic-enhanced device/resource discovery [2] [3] will be adapted to reduce maintenance costs through predictive maintenance. This will make it possible to minimize the inconvenience to citizens when there is a disservice on the system or even on the single light spot. By applying appropriate energy policies, the control system must be able to: (i) reduce energy consumption and management costs of the public lighting system; (ii) modulate light output based on vehicular and pedestrian traffic; (iii) partition the system at different levels of granularity for selective programming and switch off in case of need.

B. Blockchain-based analysis and certification of vehicle fleet data. Intelligent Transportation Systems (ITS) technologies are increasingly widespread for traffic flow detection and forecasting, vehicle fleet monitoring and real-time information visualization, in order to optimize transport network capacity and provide innovative services for users. Starting from research proposed in [4], this scenario aims to monitor

vehicles in a commercial fleet by installing an electronic device collecting significant information in order to optimize the intermodal transport of goods and passengers. Benefits of the 5G network infrastructure facilitate high-density real-time information streams. Fleet monitoring occurs by means of the aggregation of heterogeneous information concerning both the vehicles and the context in which they operate (speed, acceleration, driving style, consumption, status of roads and traffic). Gathered data will be stored in a blockchain-based distributed database to guarantee robust data integrity and to support auditing and certification activities, as required by commercial transport regulations. Finally, data mining and machine learning techniques are used to process gathered data for pattern detection, in order to optimize vehicle management as well as to provide business decision support.

C. Blockchain-based supply chain traceability. The project aims to improve supply chain management and product traceability [5] through a novel framework based on AI and blockchain technologies, characterized by the following features.

– *Blockchain data storage.* In order to ensure the integrity of supply chain data, a central authority is usually designated which is trusted by all partners, but which becomes a single point of failure for the infrastructure. Blockchain technology enables a paradigm shift toward *trustless* cooperation: reliability derives from the fact that each transaction must be validated by a *consensus* of the majority of participating agents [6].

– *Automatic business rule execution.* The simplest blockchain frameworks support only asset transfer transactions. More advanced solutions allow the execution (and validation by consensus) of Smart Contracts, *i.e.*, applications stored on the blockchain which automatically process the terms of an agreement [6].

– *Semantic-enhanced analytics.* Machine-understandable descriptive annotations can be stored into tags attached to goods. These knowledge fragments can be queried by software agents for both real-time local event detection and massive analytical processes for explainable strategic decision support [7].

D. Artificial Intelligence and Augmented Reality for last-mile logistics. The growth of e-commerce is leading to the increase of costs of the so-called *last-mile logistics* (LML) and is making it harder to guarantee timely delivery for increasingly demanding customers. Moreover, this has negative impact on urban areas, increasing traffic congestion and pollution. The project proposes to adopt AI technologies for LML management and optimization. The goal is to enable a set of innovative capabilities, thanks to the annotation and processing of information in machine-understandable formats obtained by annotating low-level data collected in real time by devices and sensors in the LML network. Properties of high bandwidth, low latency and high spectral efficiency (with support of high device density) make the 5G infrastructure an enabler for the scenario goals, which include:

– optimization of the daily load assigned to individual transporters based on the specific characteristics of the goods and the vehicles, also monitoring storage conditions in real time through 5G-equipped sensors for perishable products [8];

– continuous planning of optimal delivery routes, based on instant traffic data and road network conditions collected by the whole vehicle fleet;

– business intelligence capabilities through scalable and explainable semantic-enhanced data stream analytics;

– customer experience improvement, exploiting the 5G network to provide greater visibility by means of (i) delivery vehicle dash camera video streams, (ii) the integration of Augmented Reality (AR) with shipping notifications, and (iii) real-time AR interactions between the customer and the delivery operator for solving on-the-fly any problems that may arise, thus minimizing the costs for failed deliveries.

III. Conclusion and perspectives

This project is an important opportunity for the development of the ICT sector not only in the metropolitan area of Bari but in the whole Apulia region and possibly in other Italian districts. Leveraging 5G technology for the supervision of systems and devices in different scenarios with low-cost hardware and software solutions is an attractive proposal from a commercial point of view. Furthermore, the solution approaches aim to be general and transferable to other Smart City contexts and application areas, in order to improve the quality of life by increasing energy efficiency, security, comfort and environmental sustainability.

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