6G-BRICKS Architecture Overview and Key Innovations

Kostas Ramantas[1], Anastasios N. Bikos[2, *], Walter Nitzold[3], Sofie Pollin[4], Adlen Ksentini[5], Sylvie Mayrargue[6], Vasileios Theodorou[7], Loizos Christofi[8], Georgios Gardikis[9], Md Arifur Rahman[10], Ashima Chawla[11], Francisco Ibañez[12], Ioannis Chochliouros[13], Didier Nicholson[14], Mario Montagudand[15], Arman Shojaeifard[16], Alexios Pagkotzidis[17] and Christos Verikoukis[18, †]

*[1,2] Iquadrat Informatica SL, Barcelona, Spain, [3] National Instruments Dresden GmbH, Dresden, Germany, [4] Katholieke Universiteit Leuven, Leuven, Belgium, [5] EURECOM, Biot, France, [6] Commissariat à L'Energie Atomique et aux Energies Alternatives, Paris, France, [7] Intracom S.A. Telecom Solutions, theovas@intracom-telecom.com, [8] eBOS Technologies Limited, Nicosia, Cyprus, [9] Space Hellas S.A., Athens, Greece, [10] IS-Wireless, Piaseczno, Poland, [11] L.M. Ericsson Limited, Dublin, Ireland, [12] Brainstorm Multimedia SL, Valencia, Spain, [13] Hellenic Telecommunications Organization (OTE) S.A., 99 Kifissias Avenue, 15124 Maroussi-Athens, Greece, ichochliouros@oteresearch.gr, [14] Ektacom, Les Ulis, France, [15] i2CAT Foundation, Barcelona, Spain, mario.montagud@i2cat.net, [16] InterDigital Europe Ltd., London, UK, arman.shojaeifard@interdigital.com, [17] Satways Ltd., Iraklio-Athens, Greece, a.pagkozidis@satways.net, [18] Industrial Systems Institute (ISI) / Athena Research Center, Athens, Greece, [†] University of Patras, Greece, *Contact: abikos@iquadrat.com, phone +34-934678178*

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Abstract— **AI-driven zero-touch network automation in 6G disruptive enablers ensures security, efficiency, and scalability, particularly in cross-domain and interoperable deployment environments with non-independent and identically distributed points of presence. This paper presents a novel networking architecture for 6G cellular paradigms, named 6G-BRICKS. It aims to deliver the first open and programmable O-RAN Radio Unit (RU) for 6G networks, called the OpenRU, based on an NI USRP-based platform. The architecture also integrates the RIS concept into the Open-Air Interface (OAI), Testing as a Service (TaaS) capabilities, multi-tenancy, disaggregated Operations Support Systems (OSS), and Deep Edge adaptation. The goal is to offer evolvability, granularity, and tackle challenges such as interdisciplinary efforts and large investments in 6G integration.**

I. Introduction

6G networks are crucial for the intelligent digital society of 2030, with the European Commission supporting 5G-PPP experimental facilities and Horizon 2020 calling for pioneer research. 6G-BRICKS, the first open 6G platform, combines specialists in cell-free networking, distributed processing, and RIS using "*LEGO Bricks*" architecture tiers. It implements Software-Defined Infrastructures and Software Networks to replace physical network functions with softwarized equivalents.

The O-RAN initiative [1], [2] aims to improve O-RAN elements in the 6G era by integrating advanced technologies. The facility will deliver OpenRU, the first open and programmable O-RAN Radio Unit for 6G networks and integrate the RIS concept into OAI. 6G-BRICKS will enhance Cell-Free to O-RAN architecture by extending E2 interfaces to support CF mMIMO xApp and offering CF experimenter xApps for configuration of RAN elements.

The paper provides a comprehensive overview of the 6G-BRICKS framework, outlining its key innovation areas, primary challenges, and innovative concepts. Section II provides a conceptual architectural diagram and a depictive description of its core enabler components. Section III showcases the state-of-the-art 6G use cases that will benefit from the project's technologies. Section IV concludes the research aim.

II. 6G-BRICKS Architecture and Innovations

Sixth generation (6G) MANO orchestration, distributed supervision, and reconfigurable control logic are crucial for managing dynamic network components like cell-free, OAI, and RIS. The 6G-BRICKS experimentation plane automates the entire life cycle of intent-driven cross-platform user demands. This section will present the architectural overview of 6G-BRICKS, in brief.

A. 6G-BRICKS Conceptual Architecture

The 6G-BRICKS facility will showcase many architecture innovations, such as a disaggregated Management Plane and Operations Support System, to support extendibility, evolvability, and multi-tenancy. The 6G-BRICKS Reference architecture is shown below, including the following architectural tiers. The overall architecture is depicted in **Figure 1**, including the following architectural tiers:

- The Experimentation Plane acts as the entry point to the Facility, delivering intent driven, human-in-the-loop experimentation functionality, and supporting device testing via standardized xApps.
- The Management & Orchestration layer is deployed at each facility site as a unified controllability framework, via the groundbreaking Domain Management and Orchestration (DMO) framework. Explainable AI (XAI) mechanisms [5] are being leveraged providing explainable feedback to user experimenters.
- 6G RAN infrastructure domain where breakthrough 6G RAN technologies are integrated in reusable, self-contained

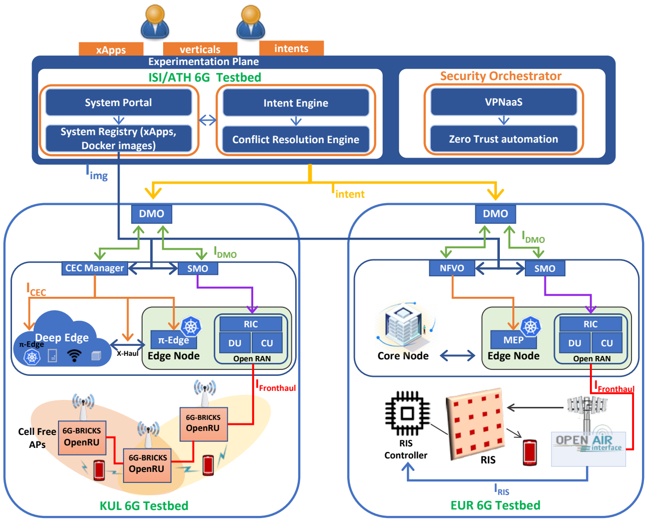

Fig. 1. 6G-BRICKS General Architecture

modules with O-RAN interfaces to ensure the openness and reusability of the developed components.

B. 6G-BRICKS Key Enablers and Innovations

The following areas, introduce 6G-BRICKS innovations in **Table I**. These innovations aim at prototyping a future 6G network architecture. Security, privacy, and trust challenges in the 6G E2E continuum coexist, necessitating the definition of different levels of abstraction to accommodate complex interactions and mitigate risks.

III. USE CASE APPLICATIONS

The 6G-BRICKS technology, with its advanced capabilities, will significantly drive the development of several disruptive 6G technologies. We enlist our two mainly deployed use cases, below.

A. Use case 1: Metaverse as an enabler of a Modern Workplace

The Metaverse is a new use case for B5G systems, utilizing XR/VR technologies for social interactions in virtual spaces. 6G-BRICKS Metaverse UCs provide a high-quality experience and immersive social interactions using the Multi-point Control Unit (MCU), which handles real-time processing of "holograms" and ensures synchronization and state consistency by processing them into a fused volumetric video. Beyond-5G KPIs are ensured via CFmmWave.

B. Use case 2: 6G applications for Industry 4.0

6G can enhance Industry 4.0 efficiency by utilizing autonomous robots, digital twinning, and XR technologies. This project UC can support Industry 4.0 autonomous robots by enabling low latency communication and synchronization between robots and remote controllers. The 6G-BRICKS RIS is leveraged to address connectivity issues caused by blocking of the mmWave spectrum.

TABLE I
6G-BRICKS INNOVATION KEY ENABLERS

Area	6G-BRICKS innovation concepts		
	Enabler	**SotA**	**Beyond-SotA**
1	**Cognitive Compute Continuum**	Edge Computing compliant with ETSI NFV IFA 029.	Automated deep edge integration Kubernetes clusters at the device-to-cloud continuum.
2	**Zero Trust Secure inter-domain interconnection and Trust establishment**	Support of NFV-SEC 013 and ETSI NFV-SEC 024 standards.	A unique 2-tiered end-to-end VPN-as-a-Service for cross-testbed connectivity and Zero-Trust security.
3	**Unified Domain Management via Explainable AI and Machine Reasoning**	Zero-touch Service Management (ZSM).	Expanded DMO engine with Explainable AI (XAI) mechanisms.
4	**Distributed Cell-Free breakthrough technologies for 6G Networks**	Cell-free networking.	Over-the-air (OTA) sync of frequency and phase in cell-free.
5	**CFmMIMO innovations and breakthrough technologies [3], [4]**	mmWave and cmWave CF technologies.	Multi-band CFmMIMO technologies; Fronthaul-aware precoding.
6	**6G-BRICKS RIS platform design and envisioned components, communication, and sensing [1]**	Open RAN components, following O-RAN specifications.	A novel RIS Control Protocol (RCP) protocol between the RIS reflector and the RIS agent hosted at the gNB.

IV. CONCLUSIONS

The paper introduces 6G-BRICKS, a hierarchical network management framework for testbed infrastructures, utilizing AI-as-a-Service and Monitoring-as-a-Service concepts for Explainable AI, achieving efficiency, energy efficiency, and sustainability.

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