

Open RAN Landscape in Brazil: Ecosystem, Research Advancements, and Technical Gaps

João Vitor Bruniera Labres, Francisco Hugo Costa Neto, Rodrigo Kenji Yaly Aoki, Iran Mesquista Braga Junior and Claunir Pavan

Abstract—Brazil faces connectivity gaps in remote regions, worsened by the high costs of proprietary 5G vendor lock-in. Open Radio Access Networks (Open RAN) offer a disruptive, cost-effective solution through network disaggregation, making it a research frontier. To understand this transition, this paper creates a thematic mapping of recent Brazilian research in the Open RAN ecosystem, highlighting national advancements in orchestration, network slicing, cybersecurity, and energy efficiency. We also map open technical challenges, from zero-touch automation and satellite integration to local hardware manufacturing and Edge-to-Cloud datacenter opportunities, providing a vision for the future of national telecommunications research.

Keywords—Open RAN, RAN Intelligence Controller, Network Disaggregation, Brazil.

I. INTRODUCTION

The continuous evolution of wireless communication requires that mobile networks to be flexible and efficient, challenging traditional Radio Access Network (RAN) architectures based on proprietary hardware [1]. To overcome these limitations, the Open RAN model emerged as an alternative that eliminates vendor lock-in by adopting Commercial Off-The-Shelf (COTS) components with open interfaces to reduce costs. This virtualized, multi-vendor architecture promotes innovation and enables the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms for dynamic network optimization [2].

Standardized by the O-RAN Alliance [3] and in accordance with 3rd Generation Partnership Project (3GPP) specifications [4], the architecture comprises the O-RAN Radio Unit (O-RU), O-RAN Distributed Unit (O-DU), and O-RAN Central Unit (O-CU), interconnected by interfaces, in the example shown in Fig. 1, the Open Front Haul (O-FH), O1, and F1. The O-RU, in some splits, handles RF signals, the O-DU facilitates communication, and the O-CU processes baseband [5]. These components can be allocated to different servers based on functional splits, providing flexibility to support various use cases and increase energy efficiency without compromising

user Quality of Service (QoS). Recognizing its strategic importance, the global industrialization of Open RAN is accelerating, supported by substantial government investments in research and interoperability labs across countries like the United States ($\approx$ US\$ 1.5B), Japan ($\approx$ US\$ 600M), Germany ($\approx$ US\$ 300M), and the United Kingdom ($\approx$ US\$ 300M) [6].

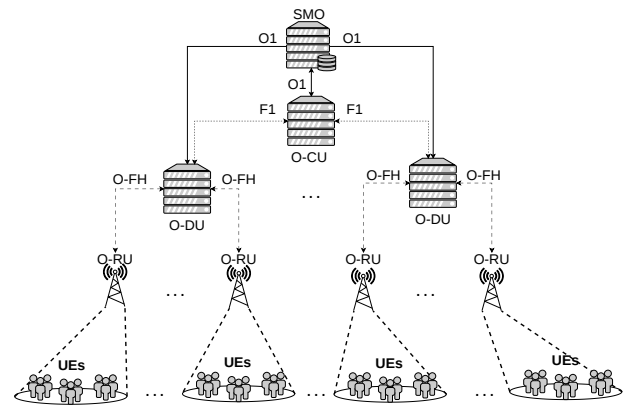


Fig. 1. Open RAN distributed topology and interfaces.

This architectural flexibility provides an opportunity to reduce Operational Expenditure (OPEX) by optimizing resource allocation. According to the Next Generation Mobile Networks (NGMN) [7], the energy consumption of network components represents a massive portion of these costs, with computation alone accounting for 33% of the energy used in data centers. Since the efficiency of hardware components directly dictates the total power draw, strategically optimizing where each virtual element is executed can significantly lower the overall financial burden. This economic efficiency is particularly relevant when considering the specific market dynamics and infrastructure costs of different regions.

In the Brazilian context, the adoption of Open RAN is currently driven by initiatives like the OpenRAN@Brasil and EXCCON – CPQD program, which promotes a local ecosystem of researchers and startups through nationwide testbeds. While high import taxes on specialized hardware remain a difficulty [8], the shift toward vendor-neutral white-box servers and disaggregated COTS components offers a path to lower the Total Cost of Ownership (TCO). This modular approach is essential for scaling cost-effective 5th Generation (5G) networks across Brazil's vast territory.

To summarize, the main contributions of this work are:

- An analysis of the Open RAN landscape in Brazil, including its current state, future perspectives, and primary

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This work has been partially funded by the Brazilian Ministry of Science, Technology and Innovation (MCTI), with financial resources from FUNTTEL and administered by FINEP, specifically under the project ERA 6G, Grant No. 01.26.0141.00, Reference 2124/25. This paper reflects only the views of the authors, and the agencies are not responsible for any use that may be made of the information contained therein.

challenges;

- A thematic mapping of the key research areas and national initiatives currently being advanced by Brazilian institutions; and
- An identification of technical gaps and open research directions to guide future developments in 5G networks.

The remainder of this paper is divided as follows. Section II presents the background of Open RAN, relevant techniques and key players in Brazil. In Section III we describe a thematic mapping of research areas in Brazil related to Open RAN. We present open challenges and future perspectives in Section IV. Section V concludes the paper with final remarks.

II. BACKGROUND

Brazil, a country of continental dimensions, faces heterogeneous challenges in expanding connectivity to isolated regions. Despite efforts to achieve nation-wide signal coverage, remote areas still lack adequate service. Data from [9] shows a disparity between urban and rural sites, particularly when analyzing the density of Radio Unit (RU) per 10,000 inhabitants, where the North and Northeast regions lag behind the Southeast.

The high costs associated with 5G deployment make adoption by new Mobile Network Operators (MNOs) a slow process, whereas established operators focus on adapting their current infrastructure. This resulted in a faster growth of the user base when compared with the last generation¹. This economic burden is largely driven by the integrated Next Generation Node B (gNB) model, where all components are bundled into a single proprietary unit, creating significant vendor lock-in. The Open RAN ecosystem emerges as an alternative to reduce costs by utilizing COTS hardware and promoting network disaggregation.

This disaggregation enables the virtualization of network functions. With the Virtual Network Functions (VNFs), a new layer of control is needed. In this case, the communication is made by adopting open interfaces (*e.g.*, A1, E2, O1, etc.) to bound the system. This flexibility allows VNFs to run on any compatible hardware, optimizing resources as needed.

This architectural disaggregation and the use of open interfaces (*e.g.*, A1 and E2) necessitate a centralized intelligence to manage the resulting complexity, a role fulfilled by the RAN Intelligent Controller (RIC). The RIC is split into two functional layers: the Non-Real Time RIC (Non-RT RIC), which resides within the Service Management and Orchestration (SMO) framework to handle high-level policies and AI/ML training with latencies above 1 second, and the Near-Real Time RIC (Near-RT RIC), which hosts xApps to execute time-sensitive optimizations between 10 ms and 1 second. As both the RIC layers and the underlying VNFs are fully virtualized, they can be dynamically deployed across the network's computational systems. Fig. 2 depicts the deployment architecture. This flexibility allows the control logic to be distributed according to the specific demands of the task, moving from centralized data centers down to edge servers.

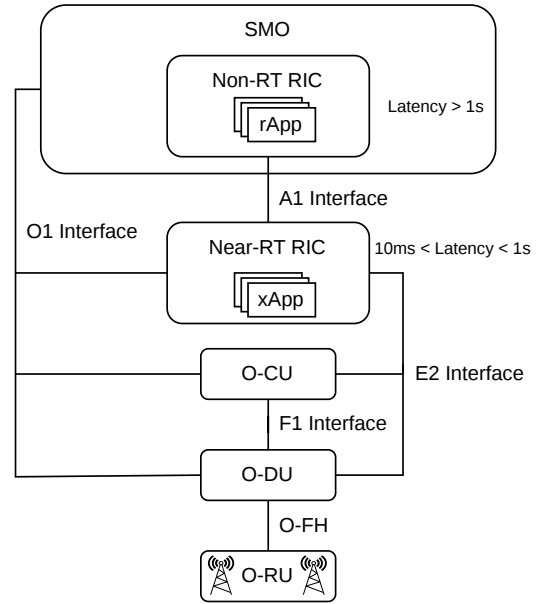


Fig. 2. Near and Non-RT RIC architecture deployment and communications.

Furthermore, as a VNF can run in any COTS hardware, all the computational infrastructure available in data centers can be used. The positioning of these data centers is also relevant. In the context of 5G, some functions demand specific computational resources that are available in data centers; others can be placed in edge servers focusing only on response delay. This paradigm is known as Edge-to-Cloud Continuum [10], which opens possibilities for optimizations and enables usage of different technologies together.

Currently, MNOs are focusing on the energy consumption of their networks, as it not only increases OPEX but also CO_2 emissions. The pursuit of reducing energy consumption has gained relevance since sustainability was identified as a priority in the transformation of operators' networks worldwide in 2023 [7]. To maximize end-to-end energy performance, it will be essential for MNOs to adopt novel approaches to network planning, deployment and management. In Brazil, TIM² and Vivo³ are advancing with Open RAN initiatives.

Some research centers are deeply involved with the development of the Open RAN in Brazil. Some of the most prominent are CPQD, Eldorado and INATEL. The project OpenRAN@Brasil also has the endorsement of Rede Nacional de Ensino e Pesquisa (RNP), connecting the institutes and universities around the country and the testbed [11].

A few universities are also developing works for the Open RAN ecosystem. In alphabetical order, we can cite Instituto Federal do Espírito Santo (IFES), Universidade Federal Fluminense (UFF), Universidade Federal de Goiás (UFG),

¹<https://telesintese.com.br/adocao-do-5g-no-brasil-e-mais-rapida-do-que-a-do-4g-diz-conexis/>

²<https://www.gruppottim.it/en/group/Activities/Innovation/open-ran.html>

³<https://telesintese.com.br/projeto-piloto-com-open-ran-entre-vivo-e-nec-avanca/>

Universidade Federal do Pará (UFPA), Universidade Federal da Paraíba (UFPB), Universidade Federal de Pernambuco (UFPE), Universidade Federal do Paraná (UFPR), Universidade do Vale do Rio dos Sinos (UNISINOS), and Universidade Tecnológica Federal do Paraná (UTFPR). These universities have been researching in the last few years, collaborating with the state of the art in Open RAN.

III. RECENT BRAZILIAN RESEARCH CONTRIBUTIONS

This section provides a literature review of recent contributions to the Open RAN ecosystem within the Brazilian research landscape. The methodology comprises a thematic mapping of recent literature, focusing on publications from 2024 to 2026. The search targeted major repositories: IEEE Xplore, Google Scholar, Sociedade Brasileira de Computação (SBC) OpenLib, and OpenRan@Brasil internal repository. For the search we used the string: ("Open RAN" OR "O-RAN") AND ("BRAZIL" OR "BRASIL") AND ("Universidade Federal" OR "Instituto Federal"). This string filters, in a broad way, papers that are from Brazilian universities and institutes, and that have Open RAN internally. As not all repositories are complete, we mixed them and found more than 500 papers.

After acquiring the corpus of papers and analyzing them, we categorized them into five primary subareas currently prioritized by the Brazilian research community: (i) Intent-Based Management and Networking; (ii) AI/ML RAN Control and Optimization; (iii) Network Slicing and Resource Orchestration; (iv) Cybersecurity and Resilience in Open RAN; and (v) Energy Efficiency and Sustainable Networking. Due to space restrictions, two representative works of each category were selected for a discussion in the following subsections.

A. Intent-Based Management and Networking

The shift towards autonomous networks is driven by Intent-Based Networking (IBN) frameworks, which aim to simplify network management by translating high-level business goals into operational configurations. Recent studies have demonstrated the integration of Large Language Models (LLMs) and chatbots to automate Service Level Agreement (SLA) management and conflict resolution in Open RAN environments.

To fix manual mapping errors, researchers from UFF and Universidade Federal do Rio de Janeiro (UFRJ) [12] propose a chatbot linked to an Open Network Operating System controller to automate Open RAN policies. Using Mininet emulations, they measured intent setup latency. Results indicate improvements in operational efficiency and service quality. The paper concludes with a forward look on the sustainable implementation of AI in O-RAN networks. UFF also addresses manual policy mapping errors in Open RAN, the authors of [13] propose AGIR, a system using NLP for intent translation and deep learning to detect conflicts. Experiments showed that the Long Short-Term Memory (LSTM) models achieved over 80% recall, outperforming the baseline. It concludes by highlighting current challenges, such as conflict resolution and integration with other network technologies.

B. AI/ML RAN Control and Optimization

Intelligence at the edge is a key component of the Open RAN architecture, realized through the RIC. Brazilian researchers have significantly contributed to this field by developing xApp and rApp that apply Reinforcement Learning (RL) for radio resource management and models to predict and mitigate network failures.

Aiming to minimize 5G downtime, a study from UFPE [14] detects and estimates complete failure durations. The authors applied a Mixture of Experts, combining an Ensemble Voting classifier with XGBRegressor models for time prediction. The system covered 97% of failure time, increasing theoretical network availability to 96%. The findings are relevant to network failure management, as they enable proactive mechanisms to deal with failures as they occur, improving service availability. To optimize Open RAN resource allocation for 5G network slices, researchers from UFF [15] propose a Deep Q-Learning (DQL) model to replace policies. Simulations shows that the agent dynamically distributed physical resource blocks among users. Results indicate DQL reduced queue latency and increased throughput over the baseline. The authors conclude DQL effectively adapts to varying network demands, proving a great solution for intelligent radio resource management.

C. Network Slicing and Resource Orchestration

To support diverse verticals such as Industry 4.0 and Cloud Gaming, efficient network slicing and orchestration are fundamental to meet QoS and SLAs. Research in this area is driven by a collaboration involving UNISINOS, UFG, and UFPR, focusing on end-to-end orchestration platforms that ensure SLA assurance across multi-tenant Open RAN deployments while optimizing the placement of virtualized functions.

To minimize SLA drift and resource usage in inter-slice scheduling, a study led by UFG [16] proposes DREAMIN, a scalable heuristic evaluated via trace-driven simulations. DREAMIN reduced resource usage in networks and lowered SLA violations in scarce ones. The authors conclude it outperforms existing models, enhancing QoS and fairness. In [17], a joint effort between UFG, UNISINOS, and UFPR proposes a method to minimize costs and reach sub 10ms latency to fast react to changes. The authors propose a RIC Orchestrator to dynamically place disaggregated Near-RT RIC components across the Edge-to-Cloud Continuum. Evaluating optimal and heuristic strategies via Kubernetes experiments, results show the heuristic scales to 512 nodes in under 10s, reducing costs.

D. Cybersecurity and Resilience in Open RAN

The disaggregation of the RAN introduces new attack surfaces, particularly in open interfaces and Application Programming Interface (API) endpoints. Recent research groups addresses these concerns by evaluating Software Defined Networking (SDN) vulnerabilities and proposing machine learning-based defenses against Distributed Denial of Service (DDoS) and adversarial evasion attacks.

In [2], researchers from CPQD mitigate signaling storm attacks in Open RAN without relying on labeled data, evaluating unsupervised anomaly detection models. The methodology

involved creating a ground-truth dataset merging real testbed logs with synthetic connection requests to test algorithms. Results showed the Clustering Based Local Outlier Factor (CBLOF) algorithm reached high precision and recall, while keeping a low inference time. The authors conclude that CBLOF enhance cybersecurity and are viable for Near-RT deployment in Open RAN architectures. To mitigate DDoS attacks compromising Open RAN slices, a team from UFPA [18] proposes an Slice Intelligent Defender xApp. Deployed on the Near-RT RIC, the xApp collects User Equipment (UE) metrics to identify threats using machine learning, subsequently disassociating malicious users. They started to test, but will validate its response time and accuracy in a later work. The authors conclude this intelligent, modular approach could enhance O-FH security while adapting dynamically to threats.

E. Energy Efficiency and Sustainable Networking

Sustainability has emerged as a critical requirement for 5G networks. Current research evaluates the power consumption of Base Stations and proposes energy-aware placement strategies for RAN components, aiming to balance high performance with reduced OPEX and carbon footprint.

To improve energy consumption, a joint study by UNISINOS and UFG [19] proposes an Open RAN adaptive load balancing framework. The authors formulated a dynamic UE reassociation optimization and validated it via custom xApps and rApps in a simulated Open RAN environment. Results demonstrate up to 94% energy savings at low loads with handover delays of ≈ 2 ms per UE. A method to minimize O-RAN energy consumption using a Mixed Integer Linear Programming model is presented in [20] by researchers from UFG and UNISINOS. Using synthetic load and topology, they evaluated the model across different profiles. Results show that hierarchical RAN topologies save up to 28% more energy than baselines and enable 15% higher centralization.

F. Mapping the Brazilian Research Hubs

From this thematic mapping, clear research poles emerge across the Brazilian territory. Institutions such as UFF and UFRJ currently lead the advancements in Intent-Based Networking and AI applied to network management. Meanwhile, a strong collaborative axis between UFG, UNISINOS, and UFPR dominates the areas of Network Slicing, Orchestration, and Energy Efficiency. Finally, UFPE demonstrates expertise in predictive maintenance, while UFPA establish itself as a hub for Open RAN cybersecurity. This distributed expertise highlights a mature national ecosystem capable of addressing the multifaceted challenges of 5G and beyond.

IV. OPEN CHALLENGES AND FUTURE PERSPECTIVES

Despite the advances in the Brazilian Open RAN ecosystem, several technical and structural gaps remain. This section outlines the primary challenges that must be addressed to achieve full-scale, production-ready deployments.

Zero-touch Network Management: The transition from manual configuration to autonomous operation is a fundamental pillar for scaling Open RAN. The challenge lies in

achieving Zero-touch Service Management, where the network can self-configure, self-heal, and self-optimize without human intervention. While current research in Brazil explores IBN and LLMs, the integration of these technologies into a unified framework that handles multi-vendor conflicts and real-time SLA enforcement remains an open research frontier.

Intelligent and Real-Time Optimizations: Although the RIC enables the execution of xApps and rApps, ensuring stability and predictability in closed-loop control remains complex. Future research must focus on the “conflicts of interest” between different ML models running simultaneously, for instance, an energy-saving xApp might conflict with a throughput xApp. Another solution is to develop multi-objective xApps and rApps, coordinating inside the algorithms.

Dynamic Orchestration and Edge-to-Cloud Infrastructure: The “Edge-to-Cloud Continuum” introduces a research area for the optimal placement of VNFs. Beyond static scenarios, dynamic and latency-aware orchestration is required to migrate functions in real-time as a response to traffic fluctuations, hardware failures, or even climate events. In the Brazilian context, this necessitates the deployment of localized edge datacenters to meet latency requirements while optimizing usage. This creates an opportunity for local cloud providers to integrate with the telecom ecosystem, providing the computational density required for dynamic Open RAN orchestration across diverse regional infrastructures.

Integration with Non-Terrestrial Networks: Expanding 5G coverage to Brazil’s remote and rural areas requires the integration of Open RAN with Non-Terrestrial Network (NTN), such as Low Earth Orbit satellites. Initiatives like the partnership between CPQD and Sateliot highlight the potential for 5G via satellite. However, the architectural adaptation of the O-FH to handle the high propagation delays and Doppler shifts inherent in satellite links is a challenge that still demands intensive research and standardization efforts.

Local Hardware Ecosystem and Industrial Policy: An impediment for Open RAN scaling in Brazil is the reliance on imported COTS components. Rising import taxes and instability in global supply chains make a domestic industrial policy necessary. Promoting the domestic production of white-box servers and O-RUs, potentially through tax incentives or the ‘Lei de Informática’ [21], is important to lower the TCO and ensure national technological sovereignty. This would not only reduce costs but also develop a specialized local workforce capable of maintaining and evolving 5G infrastructure.

Evolution Toward 6G and Organic Architectures: Looking beyond 5G, another research frontier is the development of organic network architectures that allow for incremental and flexible growth. Using 5G Open RAN and Core functions as a foundation, future systems could evolve into programmable and disaggregated environments. A focus is the integration of native AI engines based on distributed and cooperative agents across the network layers. This transition aims to integrate network optimization, ensuring that the next generation of wireless communications is natively autonomous and capable of supporting the new generation performance requirements.

V. CONCLUSIONS

In this paper, we provided an overview of the Open RAN landscape in Brazil, highlighting the transition from proprietary, monolithic architectures toward disaggregated and intelligence-driven networks. By surveying recent national contributions, we demonstrated that the Brazilian research community is actively addressing critical frontiers, such as intent-based management, AI-driven resource optimization, and energy-efficient orchestration.

However, the path to full-scale deployment still faces technical gaps. Achieving zero-touch management, resolving real-time RIC conflicts, and integrating NTN remain challenges to bridge the digital divide in Brazil's remote regions. Future work should focus on validating these open-source solutions in large-scale nationwide testbeds to ensure the resilience and economic viability required for the next generation of wireless communications.

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