Neutral Host Architecture for Post-Disaster and Rural Connectivity

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***Abstract*—The seismic events that struck Central Italy between 2009 and 2016 provide an opportunity to rethink mobile network deployment in post-disaster and peripheral zones. This paper investigates the potential of neutral host architectures, based on Open RAN (O-RAN) principles, to restore and enhance mobile connectivity where conventional operator-led deployments are not economically viable. By decoupling hardware and software and supporting virtualized, multi-operator RAN components, O-RAN enables a flexible and cost-efficient approach, particularly suited to low-density and economically fragile areas. In small towns and rural areas, the cost of infrastructure deployment becomes unsustainable for a single operator. The shared and neutral model is a cost-effective solution for radio coverage of communities that would otherwise remain unserved. We examine the benefits of this approach in the Central Italy scenario and outline a roadmap for integrating O-RAN-based neutral hosts into long-term rural coverage strategies, highlighting their role in enabling resilient and low-impact digital infrastructure.**

***Index Terms*—smart city, networks, neutral host, Open RAN, connectivity, ICT**

I. Introduction

Following the 2009 Abruzzo earthquake, the Italian Government established two Special Offices to coordinate reconstruction efforts. One of these, the USRC (Special Office for the Reconstruction of Municipalities in the Seismic Crater), which oversees 56 municipalities, has defined new procedures for post-earthquake recovery applicable to similar disaster events, such as the 2016 Norcia-Amatrice earthquake or the 2022 Ischia flood. In addition to building reconstruction, Special Offices are also tasked with promoting socioeconomic recovery and digital regeneration of affected areas. These emergency experiences, particularly in structurally fragile and low-density areas, underscore the need for inclusive and resilient Information and Communications Technologies (ICT) infrastructure to support short-term and long-term recovery options, including new mobile connectivity solutions based on shared and cost-effective models.

The University of L'Aquila has been actively involved in ICT research for regional development and to support data-driven reconstruction strategies, collaborating with the USRC [1], [2]. Among the activities are the application of Indicator Engineering to monitor post-earthquake reconstruction status and evaluate progress, along with the integration of data from the Civil Protection Department and Copernicus satellite imagery to update building inventories, conduct impact analyses, and formulate effective disaster recovery plans. Attention is also on identifying potential interferences with other domains (e.g., historical/artistic heritage, natural landscape) and developing fast web platforms using open-source tools for USRC spatial data management.

In particular, the collaboration focuses on telecommunication technologies for 5G and beyond. Key research areas include:

- Distributed mobile systems for improved 5G coverage with reduced EMF exposure and aesthetic impact;
- Lightweight fiber deployment methods for rural and small-building scenarios;
- Security mechanisms for the proposed architecture.

The USRC is committed to its digital transformation to improve its overall performance (modernization of organizational structure, improvement of citizen services, reduction of wasted time and resources) and increase the competitiveness of municipalities [3], [4]. The goal is to develop an efficient, secure, and sustainable ICT infrastructure to support this digitization.

Next-generation networks mark a technological convergence between cellular systems and Information Technology (IT), bringing significant changes to both technology and business models. It requires software-based design approaches and careful integration into local environments. A shared "neutral host" model is proposed, based on multi-tenant systems — including small cells, Distributed Antenna Systems (DAS), and Wi-Fi — to support multiple operators. In 5G networks, network slicing and specialized processing are crucial to meet diverse performance requirements while preserving net neutrality.

II. Neutral Host Networks

A Neutral Host Network (NHN) is a shared communications infrastructure that decouples infrastructure ownership from service provision, allowing multiple operators to provide services through common equipment. These can range from shared towers (site sharing) to deeper integrations such as shared radios and spectrum.

As mobile data consumption continues to grow, and with 5G introducing new deployment complexities, NHNs are emerging as scalable, cost-effective, and sustainable connectivity enablers. These networks are designed to support multiple Mobile Network Operators (MNOs) through shared infrastructure, reducing both capital and operational expenditures while improving coverage and capacity, particularly in areas where traditional deployments are either too costly or inefficient.

In this model, a third-party operator is responsible for deploying and managing the network infrastructure, such as base stations, DAS, or small cells, which can then be leased to MNOs under commercial agreements. NHNs enable more efficient infrastructure utilization, accelerate deployment timelines, and reduce both the environmental and visual impact of redundant deployments.

A particularly compelling application of NHNs lies in their capacity to extend coverage to low population density areas that might otherwise be excluded from connectivity plans due to limited economic return. Its relevance in rural areas has been explored in [5], which highlights how the 5G rollout in Ireland is constrained by low return on investment and insufficient rural coverage. The authors argue for a transformation of MNO business models toward neutral hosting to overcome CAPEX limitations and achieve more equitable service distribution.

Beyond rural inclusion, NHNs can enable innovative services in event-driven or high-density deployments. For example, [6] investigated the deployment of immersive media applications during crowded events using small cell-based NHNs. Their study demonstrated significant cost reductions and improved service quality through the use of edge computing and multi-tenancy mechanisms. These results confirm NHNs as adaptable and economically sustainable solutions for both temporary and permanent infrastructure demands.

To fully realize the potential of NHNs in both rural and urban contexts, particularly in critical or rapidly changing environments where traditional Radio Access Network (RAN) architectures fall short, there is a growing need for flexible, programmable, and vendor-agnostic solutions. The Open Radio Access Network (O-RAN) architecture, with its disaggregated design and intelligent automation capabilities, represents a promising paradigm to support and enhance NHN deployments in such complex scenarios.

III. O-RAN Architecture

The O-RAN architecture introduces a disaggregated, open, and modular approach for RAN deployment, addressing the limitations of proprietary, vendor-locked solutions. Promotes the disaggregation of network functions through the use of open and standardized interfaces, enabling interoperability between components from different vendors.

The architecture separates the RAN into three main building blocks: the Radio Unit (RU), which manages radio signal transmission and reception; the Distributed Unit (DU), responsible for real-time processing tasks; and the Centralized Unit (CU), which handles higher-layer protocols such as radio resource control. These elements are interconnected through open interfaces, enabling the independent deployment of each component to tailor the network architecture to different use cases.

A central feature of O-RAN is its intelligent control architecture, implemented through the Near-Real-Time and Non-Real-Time RAN Intelligent Controllers (RICs). These controllers enable dynamic network optimization using AI/ML models, with the Near-RT RIC handling time-sensitive operations via xApps, and the Non-RT RIC managing longer-term functions such as policy updates and model training.

This architectural separation, combined with programmability and open interfaces, allows for more efficient resource management and reduces reliance on single-vendor solutions. It also enables innovative deployment models, such as neutral host infrastructure, making O-RAN particularly suitable for rural or post-disaster scenarios where cost-efficiency, flexibility, and fast deployment are key requirements.

IV. Conclusion

Neutral host architectures are poised to play a central role in the future of mobile network deployments. By enabling efficient infrastructure sharing among multiple operators, NHNs reduce costs, accelerate deployment timelines, and reduce environmental and visual impact. These benefits are especially critical in areas where traditional single-operator models are economically or logistically infeasible, such as rural regions, temporary event zones, and post-disaster recovery areas.

The integration of O-RAN principles within NHN deployments further amplifies these advantages. The disaggregated and software-defined nature of O-RAN enhances flexibility and allows intelligent AI-driven optimization of network resources. This synergy creates a compelling framework for resilient, future-proof, and scalable network infrastructures that can adapt to dynamic service demands and heterogeneous environments.

Moreover, the economic sustainability of NHNs, particularly when supported by O-RAN, makes them highly attractive for enterprises and public institutions seeking to deploy private or mission-critical networks.

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