White Paper

O-RAN Enabling 5G Private Networks

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Executive summary

The open interface specifications produced by the O-RAN ALLIANCE are gaining significant adoption across industry verticals, bringing the benefits of interoperability, flexibility, and innovation, while contributing to cost reduction, scalability, and enhanced security.

Specifically, Private 4G/5G Networks can support various opportunities and open multiple applications for different classes of service. They are fully customizable and scalable, offering businesses a flexible, cost-effective, and independent network architecture designed to meet their specific business needs.

A Private Network is a dedicated wireless communication system that serves specific enterprise demands, providing a controlled environment with tailored network capabilities to satisfy the enterprise application requirements.

The focus in this white paper is 5G Private Wireless Networks (5G PWNs), but 4G scenarios can be considered in scope as well. See also GSA report [1] where Private Network deployment by technology is provided: according to GSA, LTE is used in many of the cataloged customers deploying private networks.

As 5G PWNs attract growing interest for their ability to deliver high performance, reliability, and security in dedicated environments, O-RAN's potential to revolutionize 5G PWNs becomes increasingly evident. By providing an open, modular, and multi-vendor architecture, O-RAN enables enterprises to build scalable, secure, and cost-effective networks tailored to their unique operational needs, independent of public telecom providers. This combination of open interfaces and customizable solutions positions O-RAN as a key enabler of resilient and future-proof communication ecosystems.

Unlike public networks, private networks are designed to support operational requirements within a defined geographic area, ensuring higher levels of performance, reliability, security, and privacy. Private Networks offer enterprises the ability to manage their own connectivity, leveraging licensed, shared, or unlicensed spectrum to create customizable solutions that align with their business goals. 5G PWNs can be operated independently or in collaboration with public networks, providing flexible access and enhanced control over network resources.

This white paper explores the adoption of the O-RAN architecture for 5G PWNs, emphasizing the advantages it offers in terms of openness, intelligence, and automation. This paper also discusses the enterprise use cases and requirements for 5G PWN solutions and demonstrates how O-RAN can effectively address the diverse needs of industries. Key enablers, such as but not limited to O-RAN Shared Radio Units (O-RU) for Neutral Host scenarios and Shared Cells for coverage-driven deployments, are also discussed, showcasing their role in expanding capabilities and improving efficiency.

Finally, this white paper highlights the evolving opportunities and challenges in the deployment of O-RAN-enabled private networks. As enterprises increasingly seek tailored 5G solutions, O-RAN's modular and flexible design ensures adaptability and scalability, supporting seamless integration with diverse technologies and devices. The open nature of O-RAN fosters innovation and vendor neutrality, enabling enterprises to avoid being tied to a single vendor. This approach also reduces costs and provides cloud-native and AI-driven optimizations, which further enhance network performance.

Abbreviations

AGV	Automated Guided Vehicles
CBRS	Citizens' Broadcast Radio Spectrum
COTS	Commercial Off-The-Shelf
eMBB	Enhanced Mobile Broadband
FH	Front-Haul
FHM	Front-Haul Multiplexer
HMTC	High-Performance Machine-Type Communications
IoT	Internet of Things
HMTC	High-Performance Machine-Type Communications
MNO	Mobile Network Operator
MOCN	Multi-Operator Core Network

[1] GSA Report: https://gsacom.com/paper/gsa-2024-a-year-in-review/

MORAN	Multi-Operator Radio Access Network
MSP	Mobile Service Provider
NPN	Non-Public Network
O-CU	O-RAN Central Unit
O-DU	O-RAN Distributed Unit
O-RAN	O-RAN ALLIANCE
O-RU	O-RAN Radio Unit
PNI-NPN	Public Network Integrated NPN
PWN	Private Wireless Networks
RAN	Radio Access Network
SNPN	Stand-alone NPN
SMO	Service Management and Orchestration
RIC	RAN Intelligent Controller
RRU	Remote Radio Unit
URLLC	Ultra Reliable Low Latency Communications
ZTA	Zero Trust Architecture

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Introduction

Based on a market's unique requirements for communication networks, no single technology can meet all of these needs, but the answer hinges on "converged" solution, and O-RAN provides required platform for converged solution of Private Networks, Wi-Fi, and 4G/5G.

5G cellular service serves as a powerful enabler of new and improved capabilities from mission critical use cases requiring reliability and security, ultra-low latency requirements, and support of massive numbers of IoT devices to enhance mobile broadband capabilities. However, the service remains limited in providing access to non-3GPP technologies. The synergies of cellular 3GPP and non-cellular (non-3GPP) can serve as the primary catalyst in enabling wireless communication opportunities in and expanding enterprise capabilities for private and non-public networks. Main focus in this white paper is on 5G Private Wireless Network (5G PWNs); however, 4G scenarios can be considered in the scope as well.

Scope of the White Paper

The focus of this white paper is to highlight the value of specific O-RAN capabilities in terms of openness, intelligence, and automation, as well other areas such as Security and Interoperability requirements for the integration of 5G Private Networks too. This paper will also cover some technology enablers as "O-RAN Shared O-RU for Neutral Host Use Case" and "O-RAN Shared Cell for Coverage-Driven Use Case."

Lastly, this white paper will present a forward-looking view of the challenges and opportunities in the near-term future for the O-RAN architecture adoption offering insights into the evolving dynamics of the 5G PWN landscape.

What is a Private Wireless Network

Different vertical markets and industry sectors show great interest in building their own PWN to leverage reduced latency, performance enhancements, higher speeds, and many advantages in terms of efficiency and security. These capabilities are related to different markets and various deployment architectures.

A PWN is similar to a public cellular network provided by licensed Mobile Network Operators (MNOs): the critical difference is that the focus of PWN is on the end-to-end enterprise application performance. Indeed, PWN is a network that is used and potentially operated by a private entity (such as an organization, government, or enterprise) to address specific needs and distinct purposes, leveraging on an extensive ecosystem of technology suppliers, system integrators, and service providers.

An additional reason for the PWN demand in recent years is the availability of market enablers, like spectrum availability such as CBRS and the and 5G advanced capabilities.

Unlike Public Networks, which are managed and operated by licensed commercial service providers, such as MNOs, to provide commercial wireless services as regulated by the government, a Private Network is a local area network (LAN) that uses licensed, shared, or unlicensed wireless spectrum and LTE or 5G technology to create a dedicated network configured to support an enterprise's specific requirements within a specific area (Factories, Campus, etc).

In short, a PWN is a dedicated network that can be deployed for a defined set of users and specific use cases, while allowing access to users from public networks when needed. While the basic architecture and technical specifications of PWN are similar to those of a public cellular network operated by MNOs, it differs in scope regarding coverage, functions, and access for devices and users.

Private 4G/5G Networks can open multiple opportunities for various applications with a different class of service: they offer flexibility as fully customizable and scalable, and provide a cost-effective, independent network architecture that reflects business needs. Spectrum is a necessary component for deploying PWNs.Table 1 summarizes the spectrum availability in the network ecosystem as established by ITU World Radiocommunication Conferences and different regional regulatory authorities such as FCC in USA and CEPT in EU.

FR1 Spectrum	Attributes	Example
Licensed	The exclusive use of over 70 bands globally for LTE, remains the industry's top priority.	PCS, AWS, C-Band

Shared	Spectrum is shared using spectrum sharing technology or allocating spectrum using the Spectrum Access System (SAS) that handles the spectrum allocation and management among different users	USA FCC, - CBRS (shared commercial use of the 3550-3700 MHz band (3.5 GHz band)), Europe 3.8-4.2 GHz (under evaluation)
Unlicensed	Spectrum is available for general use and does not require a license to operate.	Wi-Fi 2.4 GHz, 5 GHz, and 6 GHz

Table 1: Spectrum availability

Depending on the operating model, differentiated by who owns and manages the network assets, there are several motivations and use cases for 4G/5G PWNs. Starting from Release 16, 3GPP 5G Phase 2 specifications define requirements and solutions for supporting 5G NPNs at both functional and management levels. 3GPP identifies (as from 3GPP TS 22.261 specification), 5G NPNs into the following two categories:

- Stand-alone NPN (SNPN): This type of NPN operates independently of Public Land Mobile Networks (PLMNs), allowing devices to register with a PLMN, if needed.
- Public Network Integrated NPN (PNI-NPN): Deployed with the support of one or more PLMNs. The PNI-NPN can be provided as a dedicated data network or a network slice. Access control is managed through Closed Access Groups (CAGs), which restrict access to some geographic regions.

NPNs can be implemented in numerous configurations, influenced by the specific applications they support and existing regulatory frameworks.

For example, the "5G Alliance for Connected Industries and Automation (5G-ACIA)" established four fundamental deployment scenarios for NPNs [1] as reported in Table 2 below.

Deployment Scenario	3GPP NPN Type	Description
Shared RAN and Control Plane	PNI-NPN	The Non-Public Network and the public network jointly utilize the radio access network within the specified premises, with the public network consistently managing all network control functions.
NPN hosted by the public network	PNI-NPN	Both the public and the Non-Public Network traffic are managed outside the specified premises and treated as if they belong to separate networks.
Isolated NPN	SNPN	The enterprise customer owns all 5G system functions, which are deployed within their own facilities.
Shared RAN	SNPN	An enhanced version of Isolated NPN incorporates RAN sharing, enabling the gNB to serve both non-public and public subscribers.

Table 2. NPN deployment scenarios

These 3GPP-based scenarios do not encompass all existing possibilities; in fact, PWN operating models can be also classified into following main categories, according to [2] and [3]:

1. Enterprise owned and operated.
2. Enterprise owned, and Managed Service Provider (MSP) operated.
3. Enterprise owned, and Mobile Network Operator (MNO) operated (MNO acts as the MSP).
4. Neutral host owned and operated.
5. MNO owned and operated.
6. Network slice offered by MNO.

Private networks offer an adaptable solution, combining advanced technology, flexible deployment models, and customizable configurations to meet the unique and demanding needs of enterprises and industries, making them a critical component of the evolving communication landscape.

1 Enterprise Primary Use Cases and Requirements

5G PWN are transforming industries by providing secure, high-performance wireless connectivity tailored to specific operational needs. These networks offer enhanced control and security, URLLC and eMBB capabilities making them ideal for mission-critical applications in sectors such as manufacturing, energy, healthcare, and logistics applications.

When combined with O-RAN architecture, 5G PWNs gain additional flexibility, interoperability, and scalability—key features essential for addressing the dynamic demands of modern industrial environments. In deployed 5G PWN supporting autonomous transport vehicles within a manufacturing facility, O-RAN can facilitate enabling real-time communication between vehicles and control systems. This dynamic communication drastically improved logistics efficiency by allowing seamless and instant data exchanges, as clearly stated in [4].

In general, the Open RAN paradigm also enabled scalable expansion and easy integration with various devices, demonstrating the adaptability of private 5G solutions for complex industrial applications complex industrial applications.

O-RAN architecture introduces a modular, open design, providing significant advantages for industrial 5G PWNs, that allow easy network expansion as operational needs grow, supporting integration with diverse devices, and ensuring a flexible, futureproof infrastructure. This scalability and modularity help industries implement innovative use cases while enjoying the cost efficiencies and operational benefits that come from a disaggregated network approach [5].

By integrating 5G PWNs with O-RAN architecture, industries not only improve operational efficiency but also benefit from a customizable, flexible, and competitive network ecosystem, capable of evolving with the technological advancements and growing demands of modern industrial environments, while providing support for new industrial requirements as the ones described in **Figure 1**, where the most important common requirements of PWN deployments have been classified.

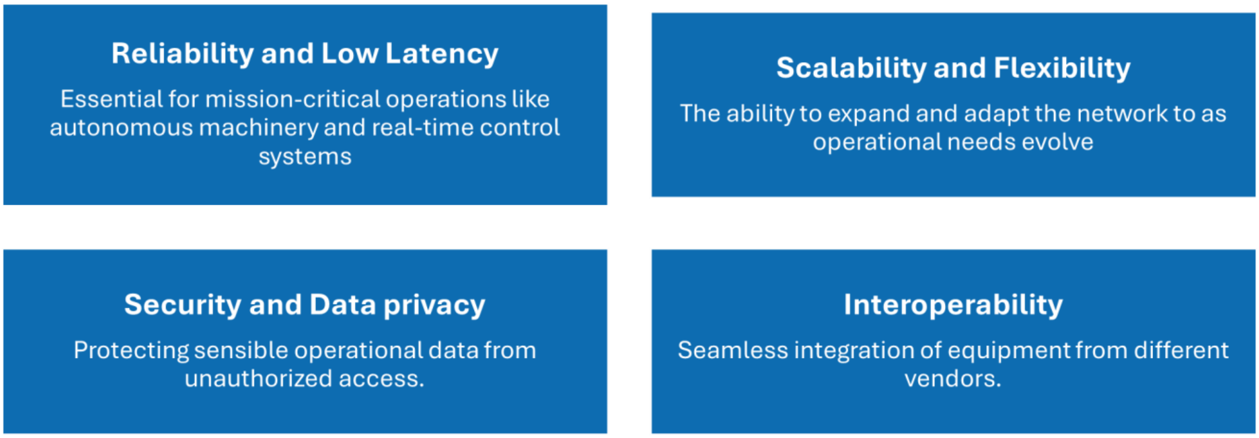

Figure 1. General 5G PWN requirements.

1.1 Use Cases descriptions

As explained in the previous sections, PWNs offer dedicated spectrum, control, and the ability to operate independently from public telecom providers, making them ideal for industries requiring the URLLC, eMBB and HMTC capabilities.

We have distilled from different use cases, seven key use cases, each exemplifying how 5G PWNs can revolutionize various industries through tailored connectivity solutions as elaborated also from [6] and [7].

Use Case 1: Industrial Automation, Smart Energy Grids, and Resource Extraction

Industries focused on automation and energy face high demands for URLLC. Factories must maintain real-time control over robotics, AGVs (Automated Guided Vehicles), and production systems. Smart energy grids depend on instantaneous data to adjust power loads and detect faults. At the same time resource extraction sites, such as mines, require secure, remote control over heavy machinery, emphasizing worker safety. 5G PWNs provide the necessary infrastructure for these complex needs, offering a dedicated spectrum that ensures uninterrupted communication. This seamless connectivity aids industries where delays can disrupt critical operations or pose safety risks. In automation, high-bandwidth and URLLC ensure the smooth coordination of robotics, real-time analytics, and predictive maintenance. Similarly, in smart energy grids and resource extraction, 5G PWN enables real-time monitoring and adjustments, optimizing power distribution and integrating renewable energy sources more efficiently while allowing remote machinery control.

Use Case 2: Smart Cities, Utilities, Construction, and Agriculture

Smart cities, utilities, construction sites, and agricultural operations demand reliable, scalable networks capable of handling vast amounts of data from various sources like sensors, IoT devices, and real-time analytics platforms. Traffic management systems, public safety, and infrastructure monitoring require real-time communication to optimize operations. Utilities depend on constant connectivity to monitor and control resources, while construction sites use drones and IoT machinery for site management. Agriculture relies on precision farming using connected sensors for tasks such as irrigation and livestock tracking tasks. 5G networks provide low-latency and high-bandwidth connectivity, supporting real-time data processing and automation. In smart cities, 5G networks enable efficient infrastructure management, ensuring the smooth operation of traffic lights, public transport, and energy grids. Utilities benefit from predictive maintenance and resource management, reducing costs and downtime. On construction sites, 5G enables autonomous machinery and real-time monitoring, while in agriculture, 5G supports precision farming through connected systems that optimize crop production and resource management.

Use Case 3: Ports, Airports, Transportation, and Traffic Management

Ports, airports, and transportation systems represent some of the most complex, data-intensive environments. These hubs require seamless, reliable connectivity to manage the flow of goods, vehicles, and passengers. In ports, this infrastructure includes coordinating cargo handling, customs, and tracking containers. Airports require real-time communication to coordinate baggage handling, flight schedules, and passenger services. In broader transportation networks, such as city-wide traffic management, real-time data on vehicle movement is essential for optimizing traffic flow and improving safety. 5G PWNs provide the high-capacity, URLLC needed to support real-time operations, enabling the smooth coordination of autonomous vehicles, drones, and IoT sensors. This coordination ensures efficient logistics and dynamic adjustments of traffic signals based on real-time analytics.

Use Case 4: Public Safety, Defense, and Emergency Response

These use cases require ultra-reliable, secure communication in unpredictable environments. These sectors rely on uninterrupted communication, even when public networks are compromised or overloaded. In addition, these systems must support real-time data transfer for critical applications such as drone surveillance and secure communication between field teams and command centers. 5G PWNs provide secure, dedicated communication channels for mission-critical operations, ensuring that first responders and defense personnel maintain connectivity during emergencies. These networks operate independently from public infrastructure, offering reliable communication in challenging scenarios.

Use Case 5: Education and Academic Research

The education sector is undergoing a digital transformation, driven by the increasing use of connected technologies, such as remote learning platforms, IoT-enabled intelligent classrooms, and campus-wide communication networks. Schools, universities, and research institutions require high-bandwidth, low-latency networks capable of supporting real-time video streaming, interactive learning tools, and connected devices used to enhance educational experience. Additionally, academic institutions must ensure that their networks are secure and scalable, as the number of connected devices and data traffic grows. With dedicated spectrum and high-bandwidth capabilities, 5G PWN ensures that students and faculty can access high-quality video conferencing, virtual learning environments, and real-time collaboration tools without disruption. Smart classrooms can leverage private 5G to connect IoT devices such as interactive whiteboards, student tablets, and classroom sensors, enhancing the overall learning experience through increased interactivity and data-driven insights.

Use Case 6: Smart Healthcare

The healthcare industry increasingly relies on digital technologies to deliver critical services, from telemedicine to real-time patient monitoring. These applications require URLLC to be capable of securely transmitting sensitive patient data across various devices. Hospitals and healthcare providers depend on connected IoT devices to monitor patient health and track medical equipment. 5G PWNs provide the low-latency, high-speed communication necessary for real-time patient monitoring, remote surgeries, and integration of IoT-enabled medical devices. The secure nature of private 5G ensures patient data is transmitted safely, complying with strict privacy regulations.

Use Case 7: Retail, Entertainment, and Financial Services

Retail, entertainment, and financial services are industries that rely on high-speed, secure networks to support a wide range of applications. In retail, these applications include intelligent checkout systems, real-time inventory management, and personalized shopping experiences powered by IoT. In entertainment, AR/VR technologies and live streaming require low-latency, high-bandwidth networks to deliver immersive experiences. Financial services demand secure, real-time communication to ensure the integrity of transactions and protect against fraud. 5G PWNs provide the speed, security, and reliability required to support these applications. Retailers can leverage private 5G to deploy IoT-enabled systems that enhance customer experience, while entertainment venues can offer high-quality AR/VR experiences with minimal latency.

1.2 Use Cases relation to O-RAN

O-RAN architecture is integral to all use cases by offering modularity, flexibility, and vendor neutrality, allowing seamless network scaling and adaptation to diverse industrial demands.

In Industrial Automation, Smart Energy Grids, and Ports, O-RAN can ensure real-time network optimization via the RIC (RAN Intelligent Controller), allowing for dynamic operational adjustments while maintaining URLLC.

As an example of application of this dynamic behavior, let's consider wind power scenarios, where rotating turbine blades create airflow fields that alter the multi-path propagation characteristics of the surrounding environment, which can affect signal stability and coverage. The blade rotation speed changes with wind speed, meaning the 5G signal impact is also dynamic. Leveraging O-RAN's RIC architecture, Artificial Intelligent (AI) algorithms can analyze the changing signal conditions caused by turbine rotation. When degradation is detected, the system dynamically adjusts user equipment access and switching strategies to avoid connection drops.

In Smart Cities, Utilities, and Agriculture, O-RAN's open interfaces support the integration of varied technologies, ensuring scalable infrastructure without vendor lock-in. For Public Safety and Defense, O-RAN's dynamic resource allocation ensures mission-critical communications remain secure and reliable during emergencies. In Education and Healthcare, O-RAN provides customizable networks, and for Retail, Entertainment, and Financial Services, O-RAN ensures fast, secure services.

2 Architectural Aspects

O-RAN architecture can be highly relevant for PWNs deployments due to its openness, flexibility, and network automation and intelligence support. Several PWN use cases and requirements as described in previous Section 1 may benefit from O-RAN deployments as a multi-vendor open environment that provides flexible and resilient solutions. The logical architecture of O-RAN [8] is depicted in **Figure 2**, and as shown it consists of various components and interfaces.

Key features of O-RAN architecture include:

- **Openness and Multi-vendor Interoperability**: O-RAN disaggregates RAN components into open interfaces, enabling interoperability across different vendors. With these, enterprises can select the best solution for their needs without being bound to an end-to-end system provided by a single vendor.
- **Modular Architecture and Flexibility**: O-RAN adopts a modular network architecture where different functional modules can be independently developed and deployed, by promoting openness and innovation. This modularity allows enterprises to replace or upgrade specific modules depending on their network requirements without overhauling the entire system.
- **Security enhancement**: WG11 is responsible of defining the requirements and specifying the architectures and protocols for security and privacy in O-RAN systems. Indeed, O-RAN enables advanced features such as intelligent, closed-loop control and automated network slicing, which enhance service-level agreement (SLA) adherence. O-RAN also supports Zero Trust Architecture (ZTA), crucial for multi-vendor environments where components from different suppliers might have varying levels of security. Thus, enterprises require to secure their private environments by using O-RAN ZTA which enables important security measures with network functions and interfaces secured to protect against external and internal threats.
- **AI/ML-driven Optimization:** O-RAN integrates AI and ML models into its architecture (as defined in the WG1) enabling intelligent, real-time network control. Intelligence and Automation are enhanced through native capabilities like SMO and RIC components, enabling essential automated operations in enterprise environments, such as real-time network optimization and dynamic resource allocation and autonomous network optimization, reducing operational complexities and improving efficiency.
- **Dynamic Resource Allocation**: O-RAN supports flexible resource allocation by dynamically associating distributed elements,

such as O-DUs and O-CUs components. Enterprises can flexibly allocate resources across hardware and software provided by different vendors as real-time demands change, reducing latency and enhancing the user experience, especially in environments with high mobility or resource-intensive applications.

- **Spectrum Flexibility:** O-RAN Open Front haul (FH) enables enterprises to choose radio units that support the operating band and power levels best suited to the specific requirements of PWN.

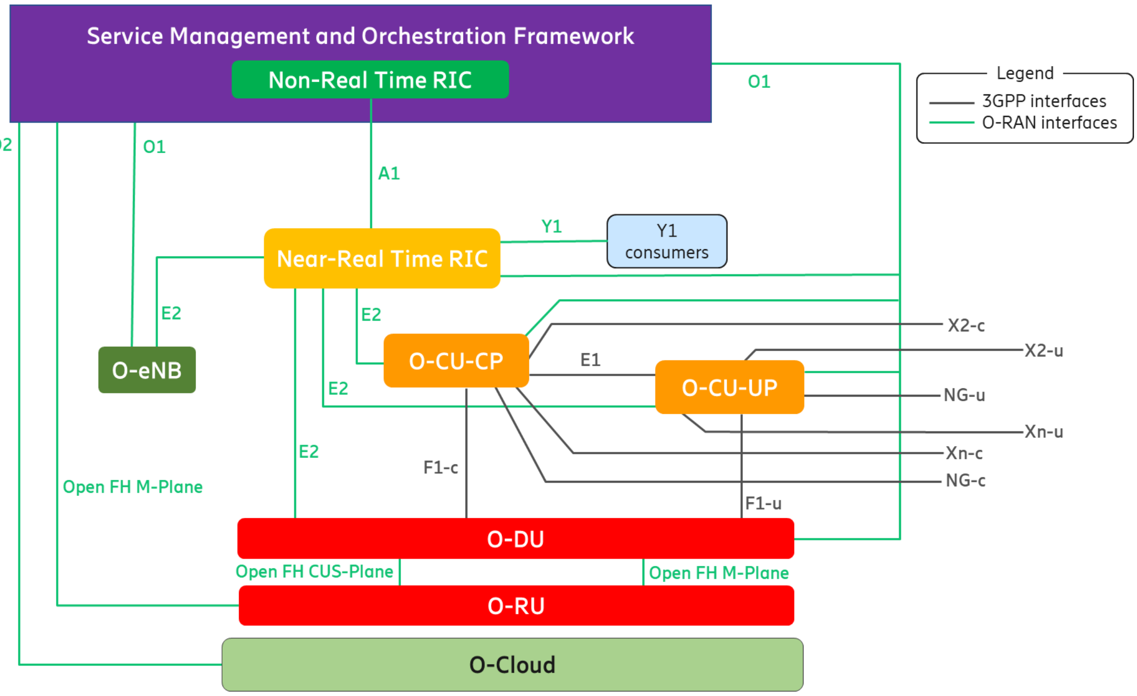

Figure 2. Logical Architecture of O-RAN

3 Enabling Technologies

O-RAN includes several enabling technologies that enable the provision of an optimized and efficient solution for specific Private use cases. The following sections describe two O-RAN Alliance-defined technology enablers for Private Networks.

3.1 O-RAN Shared O-RU for Neutral Host Use Case

For enterprises deploying, avoiding the requirement for specific Subscriber Identification Modules (SIM) or handsets/terminals for dedicated users can be highly beneficial. To achieve interoperability and accessibility, it is important for PWNs to support Neutral Hosting, enabling public users access to the PWN for voice services.

Many technologies support the Neutral Host feature in cellular networks. Multi-Operator Core Network (MOCN) is one such solution, enabling MNOs to share the entire RAN, including spectrum. In a MOCN network, the PLMN list includes all MNOs so any MNO's user may be connected. This is a simple solution, although it may have limited capacity for enterprises due to spectrum/channel sharing [11].

Multi-Operator Radio Access Network (MORAN) is another Neutral Host technology that shares the RAN but not the spectrum. With MORAN there are several options: sharing both baseband HW/SW and RUs, sharing baseband HW and RUs or sharing only RUs.

O-RAN architecture enables the latter two schemes by defining the 'Shared O-RU' feature in a function-split architecture [9], [10]. The Shared O-RU is a feature supporting multiple O-DU connections in one O-RU. These O-DUs can be from one MNO or various MNOs.

The Shared O-RU scheme supports multiple architecture options, such as hybrid and hierarchical approaches. A unique feature defined by the O-RAN for Shared O-RU is the support for an independent Shared O-RU Host, independent from participating

MNOs. This independent Shared O-RU Host Service Management and Orchestration (SMO) enables a third-party Operator (3PO) or another entity other than the MNO to play a key role in operating the Neutral Host MORAN Network.

3.2 O-RAN Shared Cell for Coverage-Driven Use Case

Another possible use case requires comprehensive coverage with sufficient but limited capacity, e.g. a PWN for IoT deployed within an enterprise footprint or for services with only a limited number of enterprise users. Here, covering a limited area with multiple cells in cost and performance is inefficient. In these cases, there is no need for a one-to-one match between an O-RU and a cell (O-DU resource). Sharing the same cell resources of an O-DU among multiple O-RUs reduces the O-DU and front-haul costs. At the same time, the O-RAN Shared Cell can achieve optimized performance with minimized downlink (DL) interference among shared cells.

The O-RAN Alliance defines the Shared Cell feature for this purpose [9],[10]. The DL signal from one O-DU resource is copied to multiple O-RUs, and the uplink (UL) signals from numerous O-RUs are combined and delivered to the O-DU. This setup enables one wide cell throughout multiple O-RUs, resulting in a cost-effective cell design minimizing inter-cell interference. Also, this feature dramatically reduces the network bandwidth between O-DU and O-RUs, contributing to significant cost reduction.

This Shared Cell may be implemented in the O-RU by cascading to another O-RU in linear topology or with the Front-Haul Multiplexer (FHM) by supporting multiple O-RU connections in a tree (star) topology.

4 Opportunities and Challenges

O-RAN architecture is a key reference platform for disaggregated RAN architecture, promoting an open and horizontal design in a multi-vendor environment. ORAN enables software-based architecture to operate on commercial off-the-shelf (COTS) servers, reducing reliance on vendor-proprietary hardware.

O-RAN is promising to offer better market competition, lower equipment costs, and improved network performance. Still, the O-RAN initiative has yet to fully demonstrate its ability to strike the right balance between performance and resiliency. Having already described the principles of the O-RAN architecture, the following summarizes some advantages/benefits and challenges associated with adopting O-RAN principles in the context of 5G PWN.

4.1 Main Challenges

- **The barrier to adoption from MNOs:** Currently, most MNOs focus their O-RAN activities on 5G public networks, even though 5G PWN offers a promising way to demonstrate the viability of O-RAN architecture before scaling it up to larger national networks.
- **Empowering Enterprise Vertical**: Confidence in 5G PWNs is increasing within the enterprise market. However, it is still uncommon for industry sectors to request 5G PWN solutions directly, as businesses are generally unaware that this type of solution could meet their needs. O-RAN could make 5G PWNs easier to tailor to enterprise needs as also described in [12]
- **Interoperability and Integration Complexity**: Achieving seamless interoperability between diverse components can be challenging. O-RAN Alliance is addressing this challenge, particularly in its Testing Specifications [6] defined to validate the end-to-end interoperability of the main components of this multi-vendor, plug-and-play architecture.
- **Evolving Standards**: O-RAN is an evolving standard, even though the technology gap between O-RAN and traditional RAN is increasingly narrowing, as reported by several MNOs [13].
- **Vendor Ecosystem Maturity**: A multi-vendor RAN deployment depends on a robust supplier ecosystem. Although many MNOs already believe that a viable open RAN ecosystem exists [14], the O-RAN ecosystem continues to develop and mature.
- **Security**: Adding new interfaces and new disaggregated network functions can increase vulnerability. Indeed, O-RAN Alliance's Security WG11 [14] is evolving the security specifications to address these risks and ensure all the expected security measures in private environments.
- **Performance and Efficiency**: O-RUs account for most of the RAN's power usage, representing approximately 80% of total consumption. Therefore, O-RUs must achieve energy efficiency levels comparable to those in traditional RAN setups. Various features were included in the O-RAN specifications for energy saving, such as shutdown options at different levels of detail, including symbol, channel, and carrier [15]. Those features are also beneficial for Private Networks.

4.2 Opportunities

- Vendor Diversity and Reduced Vendor Lock-in - thanks to the open interfaces that enable multi-vendor interoperability. Using different components from different vendors can lead to lower costs and more market competition.
- Innovation and Customization - by fostering a competitive ecosystem of third-party solutions that interoperate with each other. In O-RAN the disaggregation concept allows more options by achieving performance and improving also customer experiences by using open and standard interfaces
- Cloudification and Network Virtualization - RAN disaggregation enables application software to function as cloud-native services on a cloud infrastructure that uses general-purpose hardware and cloud platforms. This approach simplifies integration with the enterprise's IT systems in a 5G PWN.
- Edge Computing and Localized Services - with its flexibility in deploying of network functions, e.g. deploying an O-DU either at a customer premises closer to the physical site or a nearby local/edge data center.
- Improved Network Automation - by leveraging SMO, the RIC and multiple xApps/rApps optimize the network functionalities using AI/ML tools and intelligent and programmable policies: as explained in the previous sections, this is an important capability that can be also exploited in PWN, when needed. On the other hands, O-RAN is also working on integrating Non-Public Transport Management Functions (a Feature work item that will impact more WGs, i.e. WG1, WG5, WG6, WG10, WG11): the scope is to collaborate with other working groups to investigate possibility of transport inclusion to improve the overall end to end O-RAN connectivity.
- Enabling 5G and Beyond - nGRG Focus Group in O-RAN Alliance is addressing several evolution areas from O-RAN perspective

5 Conclusions

The adoption of O-RAN in 5G Private Wireless Networks marks a transformative step towards more open, scalable, and cost-efficient connectivity solutions. By leveraging open interfaces and a modular, multi-vendor approach, O-RAN empowers enterprises to build highly customized, secure, and high-performing private networks tailored to their operational needs.

With its ability to enhance flexibility, interoperability, and innovation, O-RAN is set to revolutionize enterprise networking by reducing costs, fostering competition, and enabling seamless integration with advanced technologies such as AI and cloud-native solutions. As organizations increasingly seek independent, future-proof communication ecosystems, O-RAN stands out as a key enabler, driving efficiency and unlocking new business opportunities across industries.

By embracing O-RAN, enterprises can take full control of their connectivity, ensuring robust, reliable, and intelligent networks that meet evolving demands. As the ecosystem continues to mature, O-RAN will play an essential role in shaping the future of private 5G deployments, paving the way for enhanced performance, security, and innovation.

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