BubbleRAN Multi-X Product Family MX-PDK, MX-AI, and MX-DT

Version: 2026-01

Table of Contents

1 General Description

The BubbleRAN Multi-X (MX) product family is a modular, cloud-native platform for building, automating, optimizing, and validating next-generation 5G/5G+ O-RAN networks and AI-RAN services. It provides a unified hardware–software foundation that spans infrastructure, network functions, data, and intelligence supporting the full lifecycle from experimentation and validation to production-grade deployment

The MX platform runs on a high-performance CPU/GPU architecture and delivers a turnkey, interoperable 5G/5G+ solution that combines a cloud-native O-RAN stack, AI-RAN services, and Network Digital Twin sandboxing. It supports a wide range of 5G stacks, from open-source implementations (OpenAirInterface, srsRAN, Open5GS) to industrial-grade solutions (Amarisoft, LITEON), enabling a seamless DevOps workflow from lab to production.

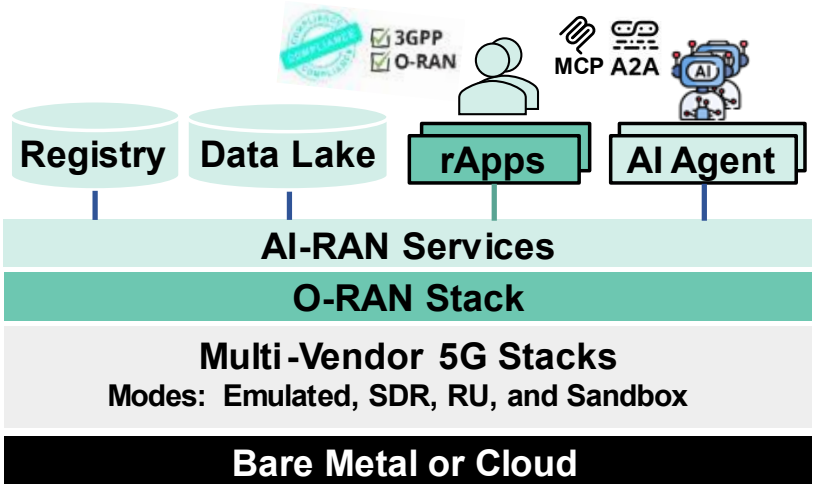


Figure 1: MX Product family and its open ecosystem

The MX product family consists of three platforms, all benefiting from an open ecosystem of reusable xApps, rApps, AI agents, and deployment blueprints publicly available through BubbleRAN's open repositories.

Product	Description	Logo
MX-PDK	Multi-vendor 5G/5G+ O-RAN Platform and DevKit https://bubbleran.com/products/mx-pdk/	
MX-AI	Multi-Agent AI-RAN Platform and Agentic DevKit https://bubbleran.com/products/mx-ai	
MX-DT	Multi Network Digital Twin Platform and DevKit https://bubbleran.com/products/mx-dt	

Together, these platforms integrate a comprehensive set of cloud-native software components through reference deployment models, enabling operators, enterprises, and developers to design, deploy, operate, and optimize high-performance, reliable, and secure 5G/5G+ O-RAN networks at scale. The MX platform is modular, easy to customize, and extensible, supporting use cases that span R&D, validation, and production operations.

Component	Definitions
O-Cloud	A telco-optimized Kubernetes platform featuring time synchronization, automatic device discovery, an optimized data plane, and eBPF-based observability.
5G Stack	5G Core (5GC), IMS, and RAN components (gNB/CU/DU) supporting Non-Standalone (NSA) and Standalone (SA) deployments across FR1 and FR2.
O-RAN Stack	Cloud-native SMO/OAM, Non-RT RIC, Near-RT RIC, and a reusable, extensible ecosystem of xApps and rApps with SDKs for programmable and intelligent RAN control.
AI-RAN Services	AI-for-RAN and AI-on-RAN workflows, agentic toolkits and catalogs, and R1 interoperability for intelligent automation and closed-loop optimization.
Observability	A multi-source data lake collecting metrics, statistics, logs, and traces from infrastructure, networks, and terminals.
Registry	A shared registry for reusable images, packages, models, agents, and deployment blueprints across the MX ecosystem.

With the MX product family, users can explore advanced 5G, O-RAN, and AI-RAN capabilities, including real-time RAN monitoring and control, cloud-native automation, and intelligent network optimization. The platform supports **(a)** O-RAN standardized interfaces (E2, A1, R1) and RIC compatibility, **(b)** AI-driven automation and optimization with AI-for-RAN and AI-on-RAN services, and **(c)** on-premises (private) cloud-native deployments, allowing customers to build a programmable, scalable, and intelligent RAN without requiring a complete overhaul of existing infrastructure. As a result, customers benefit from:

- Agility, flexibility, and performance of fully software-based 4G/5G network deployments on both bare-metal and Kubernetes-based private clouds.
- Enhanced observability, programmability, automation, and intelligence enabled by BubbleRAN's AI-RAN, O-RAN, and cloud technologies.
- Efficient design, development, and deployment of xApps, rApps, and AI agents using BubbleRAN SDKs and agentic toolkits.

The MX product family is designed to support R&D, PoC/MVP, testing and validation, and progressive rollout toward production, enabling diverse use cases and business applications with predictable performance and reliability, and targeting Technology Readiness Levels (TRL) 4 to 7.

The BubbleRAN MX product family integrates a comprehensive set of cloud-native software components through reference deployment models, enabling operators, enterprises, and developers to design, deploy, operate, and optimize high-performance, reliable, and secure 5G/5G+ O-RAN networks at scale. The MX platform is modular, easy to customize, and extensible, supporting use cases that span experimentation, validation, and production-grade operations. It includes:

With the MX product family, a user can explore all capabilities in the sphere of 5G, O-RAN and AI-RAN including real-time RAN monitoring and control, cloud-native automation, and intelligent network optimization. It introduces support for **(a)** O-RAN standardized interfaces (E2, A1, R1) and RIC compatibility, **(b)** AI-RAN Services, in particular AI-FOR-RAN and AI-ON-RAN, and **(c)** on-premises (private) cloud-native deployment models, enabling a "programmable, scalable, and intelligent RAN" without requiring a complete overhaul of existing infrastructure. With MX product family, customers are now able to seamlessly benefit from:

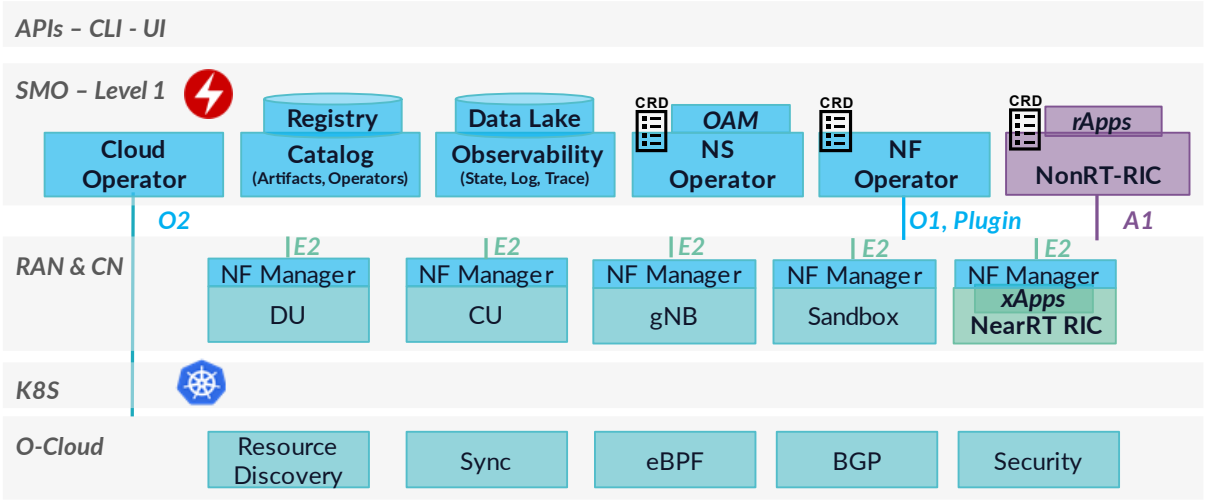
1. Agility, flexibility and performance of a fully software-based 4G/5G network deployment in both bare-metal and Kubernetes-based private cloud infrastructure.
2. Extended capabilities in terms of observability, programmability, automation, and intelligence provided by the BubbleRAN AI-RAN, O-RAN, and Cloud technologies.
3. Efficient design, development, and deployment of xApps/rApps/AI-Agents with BubbleRAN software development kits (SDKs) and Agentic ToolKit.

The MX product family is designed to support R&D, PoC/MVP, testing and validation, and progressive rollout toward production, enabling diverse use cases and business applications with predictable performance and reliability, and targeting Technology Readiness Levels (TRL) 4 to 7.

2 MX-PDK O-RAN Platform and DevKit

MX-PDK O-RAN platform includes three-man component:

1. **RAN Intelligent Controller (RIC):** Providing programmability layer with the O-RAN Compliant Near-RT RIC and Non-RT RIC with E2, A1, and R1 interfaces, xApp/rApp catalog, and their associated SDKs.
2. **Service Management and Orchestration (SMO):** providing automation layer from Day 0 to Day 2+ operations and streamlines the lifecycle management of RAN (gNB/CU/DU), UE, CN, and IMS incldluing network slicing at scale. It includes Network function (NF), Network Service (NS) and Non-RT RIC Kubernetes Operators.
3. **O-Cloud**: A telco-optimized Kubernetes cluster featuring time synchronization, device discovery, an optimized data plane, and eBPF-based observability.



2.1 BubbleRAN RIC

BubbleRAN RIC software follows the O-RAN architecture and specifications, where the Near-RT RIC resides on the RAN side (controlling O-CU/O-DU/E2 nodes via the E2 interface) and the Non-RT RIC is a logical function in the SMO framework, providing long-term policy, analytics and AI/ML orchestration via A1 and R1. It includes the following distinct software components:

- **Non-RT RIC:** enables latency sensitive services such as policy enforcement and AI/ML capabilities for the RAN elements and their resources by means of rApps. It exposes the R1 interface to rApps and A1 to Near-RT RIC. In addition, it supports custom south-bound interface for legacy RAN.
- **Near-RT RIC:** responsible for fast loop control down to sub-milli-second latency of the RAN network functions. It can host and deploy specialized xApps logic for monitoring, control, coordination, and optimization. It has E2 and A1 interfaces terminations.
- **xApp and rApp SDKs**, development kits and reusable xApps/rApps samples with built-in tests and interface to DB.

The following tables list the features sets of the **RIC** software components.

Non-RT RIC Feature Sets

Non-RT RIC	Feature Set	
Control Latency	10-100ms	
Interfaces	A1AP v4.04, R1 Interface (**R1AP v8.0** or **K8s CRD**)	
R1AP	• A1-P related services • R1 OAM related services • AI/ML related services • R1 Data management Service • R1 Data exposure services	
rApp	**Capabilities**	• Intent-driven RAN Automation (performance, monitoring, Data collection, Policy Job) • QoS/QoE Optimization (A1 Services) • CM Optimization (OAM Services) • AI-powered Slice Enforcement (A1 Services) • AI/ML deployment capabilities • SLA Assurance (A1 Services) • Slice Provisioning & Assurance (OAM & A1 Services)
	Dev. Kit	rApp SDK
	Language	Python

Near-RT RIC Feature Sets

Near-RT RIC	Feature Set	
Control Latency	300us-1ms	
Interfaces	E2 Interface (E2AP v3.0), A1AP v4.04, E2-Related Open APIs	
Service Models	• O-RAN Key Performance Measurement (KPM v3.0) • O-RAN RAN Control (RC v1.03) • O-RAN Cell Configuration and Control (CCC v3.01) • O-RAN Low Layer Control (LLC v1.0) • BubbleRAN Traffic Control (TC v0.2) • BubbleRAN Slice Control (SC v2.0) • BubbleRAN L2 Statistics (LS v2.0)	
xApp	**Example Capabilities**	• RAN and UE performance measurement (traffic steering) • UE handover control (inter/intra cell) • RAN reconfiguration (band, bandwidth part) • RAN Sensing via SRS I/Q signal samples • Interference detection • Object Detection
	Dev. Kit	xApp User SDK xApp Developer SDK
	Language	C, C++, Python
	Database	• VictoriaMetrics, VictoriaLogs, VictoriaTrace • MySQL, SQLite3 (Optional)

2.2 BubbleRAN SMO

BubbleRAN SMO software is an O-RAN compliant, cloud-native Service Management and Orchestration platform designed as a declarative, intent-driven automation framework built on top of Kubernetes. It enables end-to-end lifecycle management of disaggregated, multi-vendor RAN and CN allowing to design, deploy, operate, automate, and optimize networks from Day 0 to Day 2+ at any scale, while reducing operational complexity, accelerating service rollout, and eliminating vendor lock-in. It supports seamless onboarding of third-party network functions (NFs), including CU, xApps, and rApps, through a Container Development Kit (CDK), enabling both brownfield integration and greenfield deployments.

SMO Feature Sets

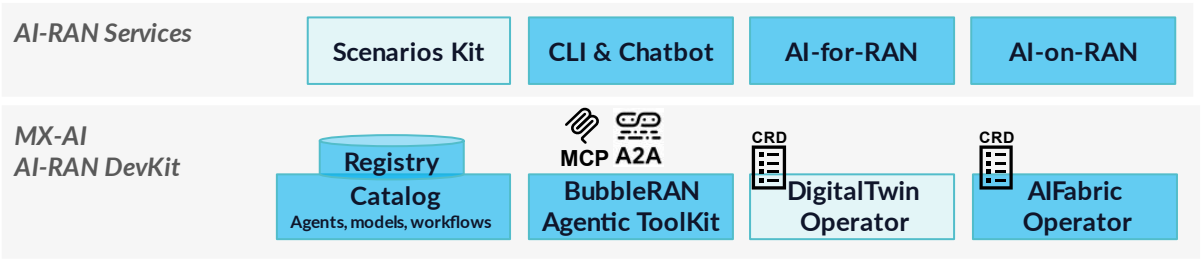
SMO	Feature Set
Operation Latency	• Day 0: 1-5s • Day 1: 1-30s • Day 2+: 1-75s
Interfaces	• Kubernetes CRD (YAML format) • REST APIs, O1 Interface • RedFish APIs (PDU)
Ops	• Day 0: Resource Discovery, Provisioning, NF Onboarding, NS Planning & Design. • Day 1: NS Scheduling, NS Deploy, NS Configuration, • Day 2+: NS/NS Reconfiguration, Test, Upgrade, Observability.
Observability	Multi-source data lake with RAN stats, logs, traces, infra resource usage, and energy consumption.
Security	• Network Isolation • Signed, Unprivileged, Rootless Artifacts • Role-Based Access Control (RBAC) • Runtime Network & Process Security • Software Bill of Materials (SBOM)
User Interface	• Comprehensive REST API • BubbleRAN CLI (BRC) • Dashboards (Grafana)
Image Registry	Harbor
Networking	Cilium (CNI), Multus (multi-networking)
Storage	VictoriaMetrics (time-series), Rook & Ceph (persistent storage)
Infrastructure	Kubernetes distribution based on Kubeadm
Container Runtime	Docker and Snap (Optional: Containerd, Podman)
Dev. Kit	CDK

3 MX-AI RAN Platform and DevKit

BubbleRAN AI-RAN services enable closed-loop automation and intelligence through AI-for-RAN and AI-on-RAN capabilities, including a network assistant on top of multi-vendor 5G networks. The solution is an extensible software stack with the BubbleRAN Agentic Toolkit (BAT) that allows customers to develop new telco agents, or to reuse, extend, and customize existing (R1-compliant) AI agents. It streamlines RAN optimization, AI/ML pipelines, analytics and insights, and dataset collection.

MX-AI includes the following components:

- **AIFabric Operator:** Cloud Native multi-agent orchstrator, Agent-to-Agent communication with A2A, exposure of algorithms, datasets and ML models with MCP.
- **Catalog:** inventory of agents, models, and workflows. Available agents are: SMO, Configuration Agent, UL Anomaly Detection Agent, API Agent, Supervisor Agent.
- **BubbleRAN Agentic Toolkit (BAT):** Agents Development Kit, CLI tool to create, build, benchmark and publish agents.



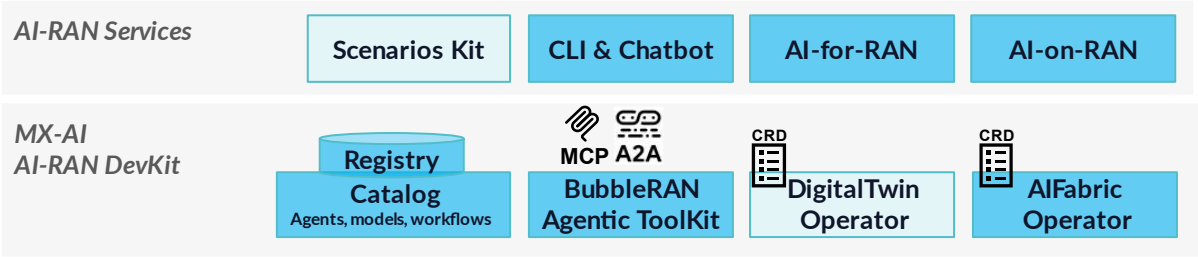
MX-AI Feature Sets

MX-AI	Feature Set
Decision Latency	1s-1m
AI-RAN Services	• **AI-for-RAN:** Intelligence executed outside the RAN software (e.g., in orchestration layers or rApps) • **AI-on-RAN:** AI-based applications and services are co-located with RAN infrastructure (e.g., edge GPUaaS)
Agent Catalog	• K8s API Agents (all operations) • Observability Agent • SLA/Performance/Anomaly Agent (EXP) • Network Configuration (EXP)
Supported Protocols	• A2A (agent to agent communication) • MCP (access external tools, prompts, datasets)
User Interface	API, CLI, UI.
Agentic ToolKit	BAT Toolkit with Pre-Built Agentic Workflows
Programming Languages	Python, Go

4 MX-DT Network Digital Twin Platform & DevKit

MX-DT is a network digital twin platform that delivers a high-fidelity network sandbox for 5G/5G+ systems. It mirrors production networks at scale with emulated UE in-the-loop, and collects, enhances, and pipelines its data for validation, AI-driven analysis, and scenario testing. With support for parallel replicas and synchronized emulation, MX-DT enables rigorous and high-fidelity network sandboxing, data generation, what-if analysis, AI/ML Validation, and quasi-real-time optimization of production networks. MX-DT leverages MX-AI DevKit and includes the following additional components:

- **DigitalTwin Operator:** Cloud-Native Digital-Twin orchestrator with state Perceptors and Replicators that reproduces the physical network (PN) and provide sandboxing environment.
    - **Perceptor:** Monitors a physical network or a replica and collects data while tracking changes over time.
    - **Replicator:** Uses data collected by the Perceptor to generate N replicas of the physical network, ensuring synchronization when required.
- **Scenario Kit:** Helps users design and deploy specific test scenarios.



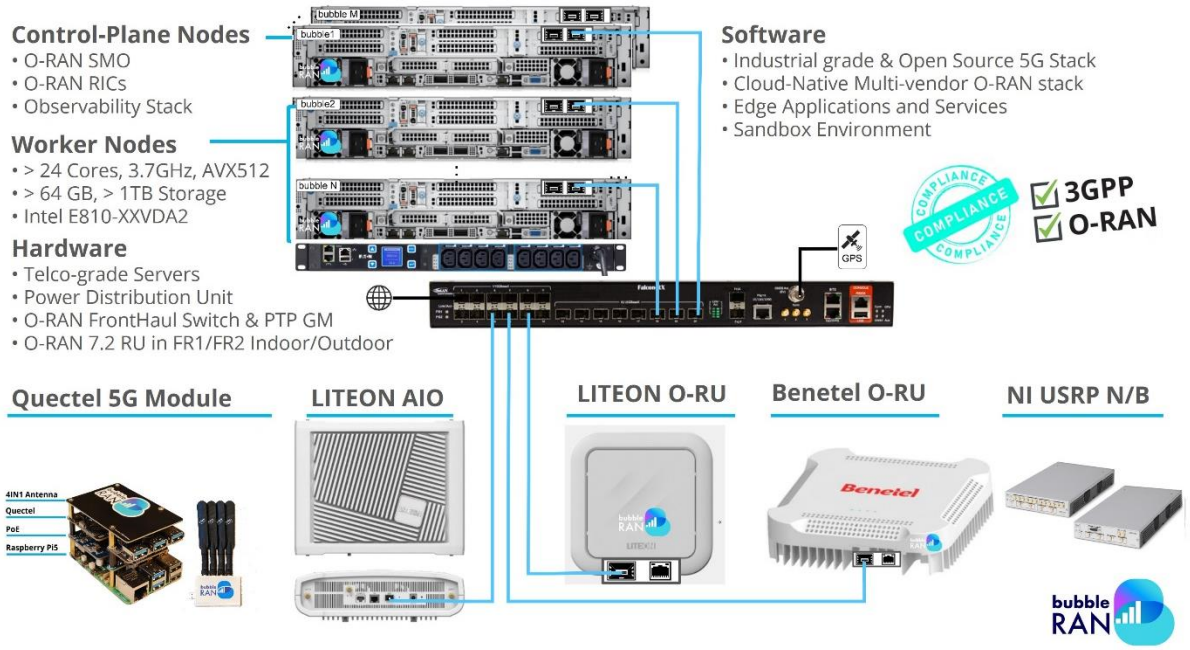
MX-DT Feature Sets

MX-DT	Feature Set
Spawn Latency	10-120s
Services	• 5G Sandboxing • Parallel Replica Sets with selective scoping • Sync or freeze each replica (Live or time-locked) • Time-aware • AI-ready
App Catalog	• Config manager • Traffic mirroring • Channel Models • Synthetic Data Generation
User Interface	CLI and UI
Dev Kit	Scenario Kit BAT Toolkit with Pre-Built DT Workflows
O-RAN Stack	BubbleRAN
5G Stack*	OpenAirInterface

**Contact us for other 5G stacks.*

5 Example Hardware Platform

Figure below shows example hardware components for the MX product family. The actual hardware configuration depends on your use case and current and future requirements. A short description of each component is provided below.



- **O-Cloud Nodes:** High performance RACK servers with cabinet or high-performance workstations. Minimum recommended number is 3.
    - **Node Spec:** x86 Arch (AMD or Intel), AVX512, >4GHz, >24C, >64GB RAM, >1TB NVMe or SSD write-intensive, Intel E810-XXVDA2, Cooling: Fan Liquid cooling (preferred).
    - **GPUs (Optional):** NVIDIA RTX PRO 6000 Blackwell Server Edition, 96GB GDDR7, PCIe 5, 600W. NVIDIA RTX PRO 5000 Blackwell PCIe 5 48GB, NVIDIA H100/H200/A100.
- **4G/5G Device + SIM Cards:**
    - **Pictel:** 5G R16 gateway and edge computing node. By stacking the high-performance Raspberry Pi5 with a Quectel 5G module and PoE+ support, Pictel delivers an ideal environment for testing "Mobile-Edge-Cloud" (MEC).
    - **Quectel**: 5G R16 Device with USB interface.
- **Small Cell:** LITEON All-In-One Small cell with E2 interface (indoor and outdoor)
- **O-RU:** LITEON or BENETEL O-RAN compliant 7.2 O-RU
- **SDR:** Amarisoft SDR50 and SDR100, USRP B2xx and N3xx with their accessories.
- **O-RAN Time-Aware switching Fabric:** FibroLAN Falcon-RX providing and PTP Grand-Master with precise time synchronization (GPS and local), PTP switching, QoS Switching and VLANs.
- **Power Distribution Unit (PDU):** Raritan PDU operated by the BubbleRAN SMO allowing you to accurately monitor and control power consumption at the level of each compute node in your O-Cloud (K8S Cluster).

6 Change History

6.1 Denim 2026-01

- Enhanced Slice Operator, AI Operator, and Terminal Operator capabilities across lifecycle, performance, and stability.
- Enhanced cloud-native Non-RT RIC, Near-RT RIC, and Proxy-E2 Agent, including performance improvements and bug fixes.
- Achieved improved compliance with O-RAN interfaces: E2AP, A1AP, and R1.
- Added RU auto-discovery and management, Multi-DU Composition Model, and advanced slice lifecycle management with QoS.
- Introduced dynamic rApp discovery, deployment, and lifecycle management.
- Expanded E2 interoperability, including support for LITEON All-in-One RAN nodes.
- Added O-RAN RC E2SM support for handover control and LLC E2SM support for sensing use cases.
- Enhanced RAN slicing algorithms, including ePR-based optimization and multi-downlink slice support.
- Introduced a multi-source data lake for RAN statistics, infrastructure resource utilization, energy consumption, and dataset export, powered by VictoriaMetrics.
- Enhanced Grafana dashboards and visualization for observability and analytics.
- Added SMO onboarding support for Amarisoft UE Simbox.
- Introduced new deployment blueprints: Multi-Slicing, ECO-RAN, AUTO-RAN, Object/V2X Cooperative Communication, Object Detection, and Dataset Generation & Export.
- Expanded enablement assets, including additional O-RAN labs, technical blogs, and updated user manuals for network, xApp, rApp, and agent deployment.

6.2 Crimson 2025-07

- Released key platform operators, including Slice Operator, Digital Twin Operator (Experimental), and AI Operator (Experimental).
- Enhanced SMO/OAM Network Service Operator for improved lifecycle automation.
- Enhanced Near-RT RIC, Non-RT RIC, and Proxy-E2 Agent, including stability and performance improvements.
- Introduced dynamic xApp lifecycle management.
- Released xApp/rApp SDKs and an initial xApp/rApp catalog to accelerate application onboarding.
- Added support for KPM v3, RC v1.x, and CCC v3.x E2 Service Models.
- Introduced A1AP integration with OEM services, exposed as Kubernetes Custom Resources (CRDs).
- Expanded hardware and RU support, including Benetel RU, LITEON RU, USRP, GPU acceleration, NUMA awareness, and CPU allocation controls.
- Added Redfish API support for Power Distribution Units (PDU) and introduced O1

interface support in SMO.
- Introduced Fault, Monitoring, Configuration, and Performance Management (FCAPS) capabilities.
- Added baseline Grafana dashboards for observability and visualization.
- Enhanced BubbleRAN CLI for improved usability and automation.
- Added support for external PNFs.
- Published enablement assets, including deployment blueprints, user guides, developer guides, and hands-on xApp/rApp labs for developers and operators.

6.3 Bronze 2024-10

- Introduced multi-vendor automation and reconciliation across RAN and Core components.
- Released the cloud-native Non-RT RIC platform.
- Enhanced Near-RT RIC with support for E2AP v2/v3, KPM v2/v3, and RC v1 service models.
- Released the Proxy-E2 Agent to enable E2 connectivity with RAN nodes.
- Introduced E2AP and A1AP exposure as Kubernetes Custom Resources (CRDs) for R1 and A1 services.
- Enhanced the SMO/OAM for improved lifecycle management.
- Added Fault Management (Experimental) capabilities.
- Improved support for large-scale deployments.
- Enhanced command-line tooling for automation and usability.
- Delivered Composition Models and deployment blueprints for Amarisoft and open-source 5G stacks, including OpenAirInterface and srsRAN.
- Added xApp labs and training modules, including initial hands-on content.
- Published updated user manuals and documentation.

6.4 Azure 2022-10

- Released the initial SMO/OAM Network Service Operator with basic lifecycle management capabilities.
- Released the Terminal Operator.
- Delivered Composition Models and deployment blueprints for Amarisoft and open-source stacks, including OpenAirInterface and srsRAN.
- Introduced O-Cloud device discovery.
- Released enhancements to the BubbleRAN CLI.
- Introduced the Artifact Registry (MX-Hub) to manage images, packages, and reusable artifacts.
- Released open documentation, including tutorials, labs, and API specifications.
- Released the initial Near-RT RIC platform.
- Introduced E2AP compatibility with early O-RAN nodes.
- Delivered initial xApp examples and the xApp SDK.
- Published academic enablement materials, including tutorials and API documentation.

7 License

This product includes software components from BubbleRAN.

- BubbleRAN software is © 2021–2026 BubbleRAN.

Redistribution of either software component, in whole or in part, without prior authorization from the respective copyright holders is prohibited.

The software is provided “as is”, without any express or implied warranties. In no event shall BubbleRAN be liable for any damages arising from the use of this software.

For detailed licensing terms and conditions, please refer to the respective license files provided with each software component.

8 Terminology

RAN	Radio Access Network
CN	Core Network
IMS	IP Multimedia Subsystem (3GPP Term)
UE	User Equipment
O-RAN	Open RAN Access Network
AI-RAN	Artificial Intelligence Radio Access Network
SMO	Service Management and Orchestration
RIC	RAN Intelligent Controller
Non-RT RIC	Non-Real-Time RIC
Near-RT RIC	Near-Real-Time RIC
E2	E2 Interface (Near-RT RIC to RAN Agent)
A1	A1 Interface (Non-RT-RIC to Near-RT RIC)
R1	R1 interface (rApps)
RF	RAN Function
E2SM	E2 Service Model
xApp	eXternal App (Near-RT RIC)
rApp	RAN Application (Non-RT RIC)
CU	3GPP Central Unit
DU	3GPP Distributed Unit
O-RU	O-RAN Radio Unit
E2E	End-to-End
AI-for-RAN	Artificial Intelligence for Radio Access Network
AI-on-RAN	Artificial Intelligence on Radio Access Network
AI-and-RAN	Artificial Intelligence and Radio Access Network
SDK	Software Development Kit
CDK	Container Development Kit
BAT	BubbleRAN Agentic ToolKit
BRC	BubbleRAN Command Line Interface
SMO-Sphere	BubbleRAN SMO-Sphere Product
RIC-Sphere	BubbleRAN RIC-Sphere Product
CSMF	Communication Service Management Function
NSMF	Network Slice management Function
NFMF	Network Function Management Function
NF	Network Function
FOCOM	Federated O-Cloud Orchestration and Management
DMS	Data Management Service
NSD	Network Service Descriptor
IMS	Infrastructure Management Service
EMS	Element Management System
TE&IV	Topology Exposure and Inventory
SDR	Software defined Radio
PDU	Power Distribution Unit

BubbleRAN headquarters:
BubbleRAN
450 Route des Chappes
06410 Biot, France
contact@bubbleran.com
www.bubbleran.com

BREAKTHROUGH TECHNOLOGIES

France - US - Kenya