WAVE

Standardize, Virtualize, Revolutionize

Reference Architecture Roadmap and Working Groups

Version 1.0

ISTO | IEEE
INDUSTRY STANDARDS AND TECHNOLOGY ORGANIZATION

Revision History

Release Level	Release Date	Description
1.0	August	Initial v1.0 published draft

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Summary

1.1. Introduction

The expansion of the satellite services market is driven by delivering access to information through connecting the unconnected, aligning infrastructure with population growth, and developing new applications and use cases for both commercial and government needs. As the industry shifts from bandwidth to bits provisioning, surging demand intensifies the pressure to avoid vendor lock, ease of operation, reduce manual operations, and "cost per bit." Consequently, Satellite Network Operators (SNOs) must innovate to lower the Total Cost of Ownership (TCO) and hasten innovation. SNOs cannot continue with traditional methods and expect to accommodate surging bandwidth needs and gear up for a 6G future. The cost-per-bit model requires evolution, and exploring revenue-generating services is essential. To develop next-generation ground infrastructures, WAVE must leverage advancements in Software-Defined Networking (SDN) and Network Functions Virtualization (NFV).

This reference architecture offers a high-level technological direction to collect feedback and achieve consensus, outline key principles guiding the consortium's decisions, and the overarching strategy necessary to fulfill its vision and mission. The reference architecture defines WAVE's effort's essential components and scope. Following the architecture, a high-level roadmap presents goals for planned releases and associated timelines. The document identifies the recommended scopes for working groups as a starting guidance to accomplish the consortium's objectives, ensuring a comprehensive approach to meeting its goals.

1.2. Mission and Vision

WAVE’s mission is to transform the SATCOM industry towards a fully interoperable ecosystem by using intelligent, open, and virtualized networks and providing standardized architecture~~s and~~ specifications.

WAVE envisions a future where SATCOM networks are built on agile, scalable, and cost-effective commodity platforms, enabling rapid acceleration of innovation in network services and operations to bring a more competitive and vibrant supplier ecosystem.

2. WAVE Consortium Vision and Tenants

The WAVE consortium is driven by an ecosystem of technology suppliers, hardware and software vendors, system integrators, SNOs and service providers. The overarching goal is to streamline the industry’s efforts along the following tenets:

2.1. Virtualization

Traditionally built on purpose-built hardware, modems have been the focus of a rising source of limited flexibility and TCO. Through virtualization, modems are disaggregated into applications and sub-applications from hardware and made software-defined and programmable. For example, "cloud modem" refers to realizing the modem functionalities over a generic compute platform instead of a purpose-built hardware platform and managing the virtualized modem application using cloud-native principles.

To the maximum extent practical, the WAVE consortium will evaluate, leverage, and verify the performance of relevant open-source communities that align with the vision and mission of WAVE, including — OPNFV[1], Akraino[2], K8S[3], OpenStack[4], and QEMU[5]— to design key solutions with programmable hardware accelerators, real-time processing, and lightweight virtualization technologies. Leveraging these standards offers significant advantages, performance verification challenges remain, and careful consideration of mission-specific requirements will determine whether the performance meets the necessary criteria.

2.2. Openness

To exploit the cloud-scale economics and service agility, open interfaces with reference designs will be salient and democratize innovation. Such an effort shall boost a vibrant supplier ecosystem and promote interoperability and speed to market. Vendors and Operators shall be able to create a common ground to introduce their services or customize the network to suit their unique needs.

3. Reference Architecture

The standardization of the reference architecture architecture, shown in Figure 1, should be based on well-defined, standardized interfaces to enable an open, interoperable, next-generation ecosystem. This architecture is built on the principles of openness to accelerate the adoption of virtualized satellite ground infrastructures with embedded AI-powered control. This architecture represents a logical representation of architectural components for disaggregation, which the responsible wor king groups shall further refine. The interfaces and functional components are

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[1] S. Guerassimov, E. Cordeiro, and L. Schwaighofer, "NFV and OPNFV," Network Architectures and Services, 2016, [Online]. Available: https://tinyurl.com/25ozgme5

[2] R. Arutperunjothi and B. Preston, "Akraino Edge Stack," Akraino Wiki, 2020, [Online]. Available: https://tinyurl.com/2bnt3bxr

[3] Kubernetes Website, "Learn Kubernetes Basics," 2022, [Online]. Available: https://bit.ly/3SgqBYh

[4] OpenStack, "What is OpenStack," OpenStack Homepage, 2021, [Online]. Available: https://bit.ly/3iRobPx

[5] QEMU, "About QEMU," QEMU Documentation, 2023, [Online]. Available: https://bit.ly/3qJrwaX

expected to be fully disaggregated by working groups to management, user, and orchestration planes.

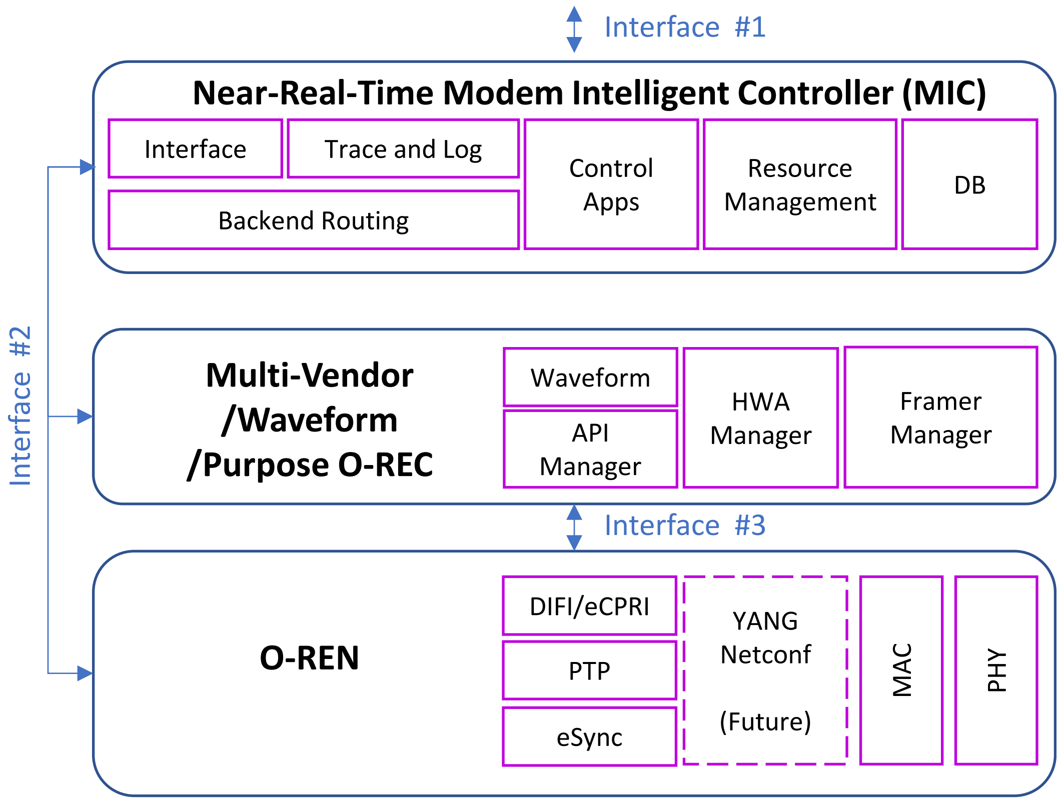

Figure 1. WAVE Consortium Reference Architecture

3.1. Modem Intelligent Controller (MIC)

The Modem Intelligent Controller (MIC) is designed to serve as a centralized repository for higher-layer applications that create applications from service chains across both the Open Radio Equipment Controller (O-REC) and the Open Radio Equipment Node (O-REN). It incorporates two distinct interfaces to streamline operations: Interface #1 offers a high-level Application Programming Interface (API) to management and orchestration functions such as OpenStack and Kubernetes, facilitating the management and deployment of service chains throughout the O-REC and the O-REN. Interface #2 grants direct control over deploying applications within the O-REC and O-REN to form these service chains and efficient and targeted MIC application rollout. The MIC should also define the demarcation between orchestration, management and user planes.

The MIC is envisioned to deploy functions leveraging embedded intelligence, such as QoS management, mobility management, connectivity management, seamless handover control and much more, via a robust, secure, and scalable platform that allows for flexible on-boarding of third-party control MIC applications, which will interface with O-REC and O-REN applications. WAVE will define and publish interfaces #1 and #2. In the subsequent releases, MIC will execute the AI models based on traffic prediction, spectral changes, policy decisions, etc., to change the functional behavior of the network through the deployment of service chains.

In addition to software and hardware disaggregation, the Control Plane (CP), User Plane (UP), and Orchestration Plane (OP) will be decoupled to exploit the benefits of SDN while inserting intelligence. Since the CP has more variability, such a decoupling of UP will allow it to get more standardized and enable nonlinear scaling from the CP. Further, this mechanism allows for advanced control functionality, increased efficiency and better modem resource management. These control functionalities will then leverage analytics and data-driven approaches, including advanced AI/ML tools. WAVE shall aspire to lead the industry in developing AI-enabled MIC workgroups to drive SNO proof of concepts and tests.

3.2. Open Radio Equipment Controller (O-REC)

The basic functions of the O-REC are implemented according to the control commands issued by the MIC through Interface #2, providing the ability to identify the waveform Virtual Network Functions (VNFs) instances. The O-REC will be responsible for cataloging and lifecycle management of waveforms, including instantiation, scaling, updating, and/or upgrading, as well as termination of VNFs. The O-REC will distribute capacity across multiple modem elements with security isolation, virtual resource allocation, CPU virtualization, accelerator resource encapsulation, etc. Relevant interfaces shall be defined by WAVE and published to allow for interoperability. The O-REC uses interface #3 as an open application deployment interface for deploying applications in the O-REN. This interface is a dynamic resource management conduit for memory, accelerator resources, and application protocols.

3.3. Open Radio Equipment Node (O-REN)

The O-REN function includes real-time PHY and potentially MAC functions, baseband processing and radio frequency processing with standardized, digitized interfaces (e.g., DIFI) towards the antenna and network interfaces. For the initial release, the WAVE consortium shall support the Digital IF/RF standard as defined by the Digital Intermediate Frequency Interoperability (DIFI) Consortium. O-REN also tracks, coordinates, and allocates memory and accelerator resources to support applications.

4. WAVE Roadmap

The release roadmap outlines an efficient execution management strategy. It creates a standardized process for coordinating crucial activities necessary to deploy WAVE-compliant successfully. WGs may modify deadlines and scope as appropriate.

The WAVE working group activities will focus on, but are not limited to:

- Gathering and consolidating prioritized technology requirements.
- Identifying and engaging with ecosystem members will deliver the various hardware and software reference designs that meet harmonized SNO needs.

- Publish a Release Definition Document mapping the prioritized features to a roadmap of releases.

4.1. Timelines

The timeline below represents an aspirational schedule for the working groups to fulfill.

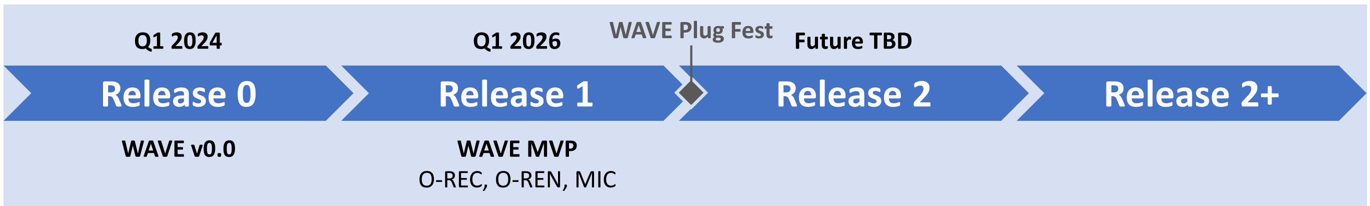

Figure 2. Release timelines

4.2. Proposed Release Content

The proposed release content is initial guidance for the WGs. WGs are responsible for refining, re-defining, re-scoping, and issuing official roadmaps in conjunction with board approval defined within the scope of their charters.

4.2.1. O-REC and O-REN

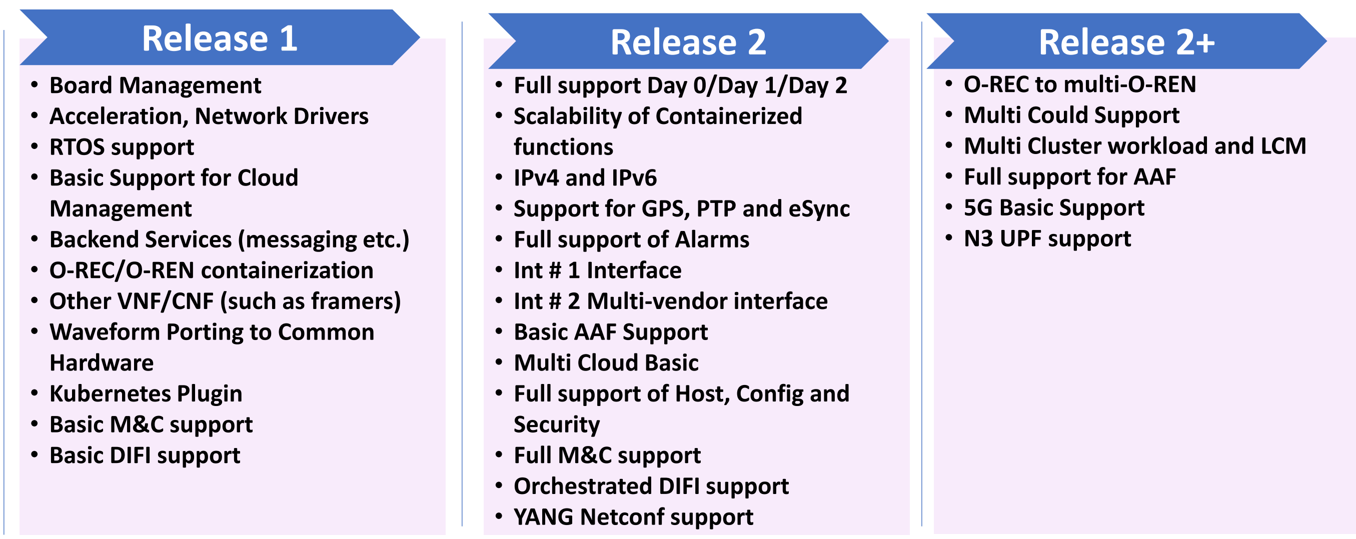

Figure 3. O-REC and O-REN Contents

4.2.2. Modem Intelligent Controller (MIC)

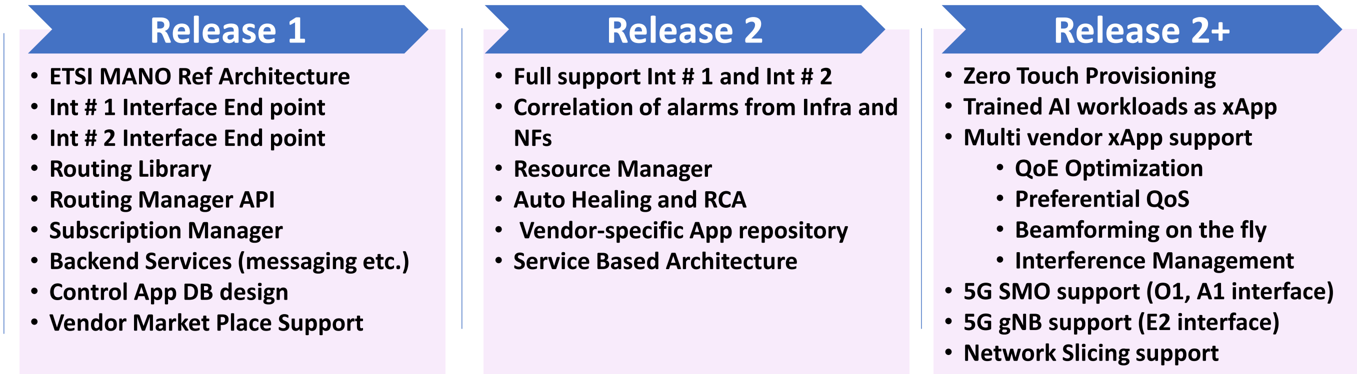

Figure 4. MIC Contents

4.3. WAVE Release 0: Initial baseline

- Draft specifications in early 2024.
- Architecture to implement waveform only on COTS hardware.
- Acceleration hardware based on PCI express in-line FPGA cards.
- Disaggregation at the HW and SW level.

4.4. WAVE Release 1: Initial Industry Collaborative Release

- Focused WGs defining and specifying O-REC, O-REN, MIC, and Interfaces #1-#3
- Service Management and Orchestration.
- Open Application Programmable Interfaces (APIs) are published to interoperate with O-REC, O-REN, and MIC.
- Vendors participate in Plugfest in conjunction with the completion of Release 1.
- A certification process for compliance, supplier validation, and WAVE-validated/tested products.

4.5. WAVE Releases 2, 2+ (future considerations)

- Aggregates vendor requirements mapping to multiple inputs from SNO, service providers, and orchestration technologies.
- Initiates WAVE Road mapping process to define the delivery of required features across multiple releases and timeframes.
- Potentially support integration with 5G implementations, potentially including enhanced Common Public Radio Interface.
- The initial baseline of WAVE Open Gateway: a framework of APIs designed to provide developers with access to APIs and applications, which will streamline operations for service providers and SNO network operations.

5. Key Working Groups (WGs)

WAVE Working Groups (WGs) will methodically advance through gathering and mapping requirements on a regular schedule. Satellite Network Operators (SNOs), Technology Original Equipment Manufacturers (OEMs), and Cloud Infrastructure Providers/Hyperscalers are invited to contribute, and these contributions will be integrated into requirement documents for vendor review and compliance.

5.1. WG1: O-REC and O-REN

The primary focus of WG1 will be to decouple the modem software from the underlying hardware platform and to architect technology and reference design(s) that would allow standard common hardware platforms to be leveraged, including the O-REC and the O-REN. The objective is to allow interoperability across multi-vendor supported O-REC and O-REN, as well as real-time scaling and waveform selection.

WG1 will work to standardize orchestration/automation APIs for the O-REC and O-REN to support the discovery, configuration, and management of virtualized modem elements, including placement and dynamic resource management, fault tolerance, and auto-scaling based on real-time usage monitoring. The architecture and integration will work with open-source cloud/MANO software such as OpenStack and Kubernetes. Additionally, WG1 shall work on virtualizing the modem software stack towards a clean hardware/software separation. Technologies include real-time hypervisor support, acceleration of compute-intensive workloads, signal processing, and beam forming through heterogeneous computing leveraging CPU and programmable accelerators.

5.2. WG2: Modem Intelligent Controller (MIC)

Traditionally, resource management and CP functions are vendor-specific and embedded in the modem. WG2 will focus on architecting the software programmable MIC to bring a higher degree of flexibility to the modem as well as ensuring performance consistency across the network in a genuine multi-vendor and open environment. WG2 will focus on architecting the MIC platform to host and manage functions such as mobility management, load balancing, QoS management, interference management, scheduling policies and future slicing-related optimizations etc., in a vendor-agnostic fashion. WG2 will also focus on architecting and defining an open and inter-operable Interface # 1 and Interface # 2 (Reference, Figure 1)

5.3. WG3: Open Interface Work Group

Based on operator requirements, there could be multiple O-RENs being supported by a single O-REC in the future, spread across geographically dispersed locations.

This work group aims to provide fully operable multi-vendor profile specifications for Interface # 3 (Reference, Figure 1).

Note: WAVE consortium will periodically evaluate the WGs and modify their scope or add new WGs as necessary

6. Conclusion

With the surge in data needs, Satellite networks and the equipment that runs them must become more software-driven, virtualized, flexible, intelligent and energy-efficient. WAVE consortium is focused on scaling up the productization of this next-generation technology driven by an ecosystem of technology suppliers, system integrators and SNOs, making the networks more open and smarter than previous generations.

Technologies from open source, terrestrial 5G, and open white box network elements might be important software and hardware components of these reference designs. The Release features and requirements will form the basis for issuing ribbons and badges to vendor products.

Join WAVE Working Group(s) to participate in existing and future releases.

Click on our website here.