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Decentralized Multi-Party Multi-Network AI for Global Deployment of 6G Wireless Systems

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***Abstract*—Multiple visions of 6G networks elicit Artificial Intelligence (AI) as a central, native element. When 6G systems are deployed at a large scale, end-to-end AI-based solutions will necessarily have to encompass both the radio and the fiber-optical domain. This paper introduces the Decentralized Multi-Party, Multi-Network AI (DMMAI) framework for integrating AI into 6G networks deployed at scale. DMMAI harmonizes AI-driven controls across diverse network platforms and thus facilitates networks that autonomously configure, monitor, and repair themselves. This is particularly crucial at the network edge, where advanced applications meet heightened functionality and security demands. The radio/optical integration is vital due to the current compartmentalization of AI research within these domains, which lacks a comprehensive understanding of their interaction. Our approach explores multi-network orchestration and AI control integration, filling a critical gap in standardized frameworks for AI-driven coordination in 6G networks. The DMMAI framework is a step towards a global standard for AI in 6G, aiming to establish reference use cases, data and model management methods, and benchmarking platforms for future AI/ML solutions.**

I. Introduction

Despite the promise of Artificial Intelligence (AI), there remain obstacles to its wide adoption in communication networks. For example, the introduction of software-defined elements, such as the O-RAN Alliance's RAN Intelligent Controllers (RICs) [1], enables the control and management of Radio Access Networks (RANs) by multi-party applications. However, the control and management capabilities of these software-defined elements do not extend to optical networks, and related AI functions are still under active research and standardization [2].

The high throughput and low latency expected for many 6G applications are such that the optical links can no longer be simply viewed as fat pipes, but instead must be managed together with the radio resources for end-to-end efficiency and scale [3]. AI controls can play an important role in managing the diverse and complex requirements of these different network platforms. However, AI research is largely siloed within the wireless and optical research communities, and there is little understanding of how AI-based controls might interact and jointly manage resources across network domains [4], [5]. Consequently, there does not exist any framework or accepted practice for AI-based control and management across radio and optical fibre networks.

Our goal is to propose such a framework and enable the creation of intelligent, zero-touch networks that can configure, monitor, and repair themselves at a large scale. The core of our research revolves around understanding the dynamics of multi-network orchestration, achieving a seamless integration of AI-driven controls across radio and optical fiber networks. The potential impact of this work is amplified by the current lack of a unified framework or standardized practices for such coordination. This paper proposes a Decentralized Multi-party, Multi-network AI (DMMAI) framework for designing mobile networks that seamlessly integrate AI, enabling a holistic evaluation of AI-driven control mechanisms. The proposed solution is the first step in developing a reference framework for AI that will pave the way toward global validation and standardization of AI approaches in large-scale 6G networks. It will enable the development of reference use cases, data acquisition, and generation methods, data and model repositories, as well as curated training and evaluation data.

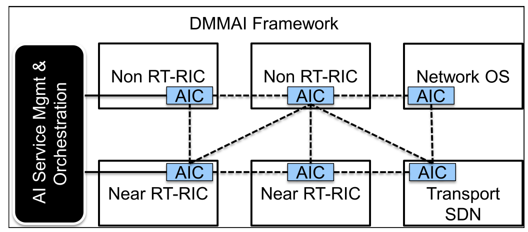

Fig. 1. Decentralized Multi-party, Multi-network AI Framework consists of an AI control toolbox that facilitates end-to-end AI services.

II. DMMAI Framework

We have created the DMMAI framework to tackle the complexities of embedding AI/Machine Learning (ML) technologies into network architectures and to facilitate cohesive interaction across all network elements in both the radio and optical domains. It is designed to form a unified 'multi-network' approach. Our framework is also meant to serve as a foundational blueprint, providing a detailed yet adaptable structure for further development and enhancements. While it outlines the essential components and functionalities needed for effective AI/ML integration, it also maintains the flexibility to accommodate future expansions and technological evolutions, ensuring its applicability and relevance in the dynamic landscape of network technology. To achieve this, we will leverage the O-RAN architecture, an open-source platform enabling multi-party applications (xApps/rApps) within a RIC. Our primary objective is to examine the practical applications

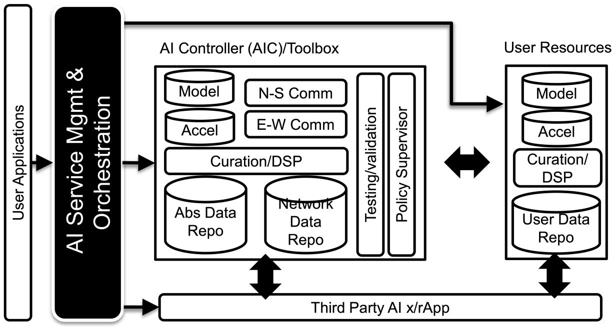

Fig. 2. The AI controller or toolbox is composed of a set of repositories, virtual network functions, and interfaces. These interact with both user resources and x/rApps in order to carry out AI-based network functions/control.

of these control mechanisms and their potential for 6G networks.

Figure 1 depicts the overall architecture of our proposed framework. It is composed of an AI Controller (AIC) and a cross-controller network architecture. The AIC resides in various software defined networking environments including: near-Real Time (RT) RIC, non-RT RIC, transport Software-Defined Networking (SDN), and Network Operating System (NOS). In addition, an AI service management and orchestration platform facilitates end-to-end AI services within the network.

The AIC plays a pivotal role in enhancing the DMMAI framework's effectiveness and versatility. By decoupling various functionalities, it facilitates a powerful framework structure where AI controls can be integrated with different network nodes. This integration supports both North-South (N-S) and East-West (E-W) communication flows, laying a foundation for the development and implementation of advanced algorithms.

One of the key advantages of this approach is the facilitation of group or swarm intelligence. This concept involves the coordinated actions of various network nodes, where decision-making and operational strategies are informed and enhanced by shared data insights. The simplicity and modularity of the DMMAI framework simplify the integration and testing of different AI-based platforms, while also allowing for the incorporation of diverse technological solutions. This flexibility ensures that the framework remains adaptable and scalable, capable of evolving with technological advancements and emerging network needs. The DMMAI framework's design thus offers a unique balance – it is detailed enough to provide clear guidance on essential components, yet open-ended to allow for future extensions and enhancements, ensuring its long-term relevance in the dynamic field of network technology.

Reference elements of an AIC are shown in Figure 2. These reference elements are not intended to be comprehensive, and the framework can be further customized. The four classes of elements included here are: 1) data management (curation/DSP, abstracted data repository, and network data repository); 2) model management (model repository and accelerators); 3) inter AIC communication (N-S, E-W APIs/protocols); 4) AI management (testing/validation controller, policy supervisor). Each of these building blocks interacts with the respective network elements accessible to the controller in which they are embedded. The building blocks may further interact with AI x/rApps or external controllers or orchestrators through the respective RICs as well as user AI resources. The network data repository is intended to house the data accumulated from the respective telemetry system in the given network. The abstracted data repository maintains the processed and curated data for application use. Specific AI workflows would be implemented by an orchestrator using these tools within the network. User/application resources include similar data and model management tools for the user applications. The AIC can be used to configure the network in order to best support different user AI applications depending on the network application domain. As an example, x/rApps might be deployed that would utilize an AIC to optimize a private O-RAN network to support AI-driven automation in an industrial factory environment. The orchestration of such applications would be managed through the orchestration system, of which the AI service management aspects are modeled as the AI Service Management and Orchestration element. This would include a northbound Application Programming Interface (API) for user applications.

The specification of the different AIC elements depends on the networks and nodes in which the AIC is embedded, which is network technology dependent (e.g., radio vs optical). For example, the radio AIC can leverage O-RAN, whereas the optical AIC can leverage Open Network Operating System (ONOS). The technologies that they could control range from radio beam forming and spectrum controls to optical signal routing and power management.

III. Conclusion

This paper presents a vision for the evolution of 6G communication networks through the DMMAI framework. Moving beyond traditional data delivery, our approach focuses on developing networks into decentralized intelligence and response systems, essential for meeting the complex demands of future communications. Our work lays out a foundational strategy for AI-driven 6G networks, encapsulating the need for intelligent, flexible, and secure network systems. The DMMAI framework is designed to seamlessly integrate AI/ML technologies into network architectures across both radio and optical domains. Its structure is both detailed for immediate implementation and adaptable for future enhancements.

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