AI-NATIVE 6G: AUTONOMOUS HIERARCHICAL AGENTIC RAN AND CORE ORCHESTRATION

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Abstract:
The ultimate vision of 6G technology is such a network, which is capable of automatically operating and smartly taking over everything from the radio signals to the core cloud. In this paper, we suggest an innovative, human-like method to create that future: a layered AI agents team. Just think of a pyramid-like structure where the lowest agents deal with the very urgent matters such as spectrum allocation, while the higher-level manager agents are in charge of the long-term goals such as quality of service from end to end. These AI colleagues will learn to collaborate with each other by negotiating and exchanging information to make the best possible decisions. We lay out the design for this agentic structure, discussing how it permits the performing of seamless, self-directed orchestration. This method has the potential to deliver not only the 6G networks that are immensely more efficient and prompt but also the ones that are completely self-driving.

Keywords:* *6G Networks, AI-Native Architecture, Autonomous Orchestration, Hierarchical Multi-Agent Systems.

I. INTRODUCTION

The transition to sixth-generation (6G) wireless technology is not simply an enhancement in connectivity but a complete overhaul of the communication system. It is, instead, an intelligent, self-managing infrastructure that humans will not have to manage at all. The ultimate goal is to accomplish total network management without humans being part of the process, where radio access networks (RANs) and core networks work together flawlessly and in real time to meet even the most demanding service levels. Nonetheless, the prevailing practices usually consider RAN and core optimization as two individual and disconnected challenges, which results in the performance being less than optimal on the global scale and the operational complexity being very high. This situation underscores a very important issue: there is no single control plane powered by AI and existing across all domains of the network, which means there is no capability for holistic decision making.In this article, we present a new hierarchical agentic structure aiming at closing this gap. The framework adopts a multi-tiered ecosystem of co-working AI agents built on the principles of organization. The specialized agents that provide the necessary real-time, fine-grained control of RAN resources like spectrum and scheduling occupy the lower levels of the hierarchy. The managerial agents at higher levels deal with wider objectives such as end-to-end service level agreements and cross-domain resource pooling. However, these agents do not work alone; they have developed a coordinated way of working together through structured communication and negotiation which results in a unified intelligence.It is the entire design of this architecture that we reveal, specifying the roles, interactions, and learning mechanisms that allow for the smooth operation of the orchestration. The unification of control along the RAN-core boundary opens up the agentic approach to yielding operational efficiency, agility, and autonomy

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at levels never experienced before, which in turn provides a design blueprint for the truly self-driving 6G networks of the future.

II. LITERATURE SURVEY

The vision of autonomous end to end network management is regarded as one of the main ideas in the research of 6G and the key roadmaps for AI native design have established it as a principal concept. This shift of making a switch from artificial intelligence as a powerful tool to the network itself, which in turn requires new control systems, is enormous. In the past, automation has been developed separately for various network segments. There is a lot of extensive research going on about the machine learning application, mostly on reinforcement learning, to optimize the Radio Access Network for the dynamic scheduling of tasks. On the other hand, there have been advances in software-defined networking and intent-based systems that were aimed at automating service delivery in the core. The separate evolution raises a serious issue of coordination where the independent optimization policies can contradict and thus, the overall network would be less efficient.The hierarchical control is a well-known principle in engineering that has been used to manage network slices in telecommunications. In the same vein, the application of Multi-Agent Systems for the control that is distributed and scalable is documented in smart energy grids, for example. Recently, the combination of these ideas has been attempted in the studies and multi-agent solutions have been even proposed in the context of specific 6G resource challenges. The downside of these proposals is that they very often consider only one part of the network, like RAN for example, or they make use of agents with the same roles.Therefore, it is already my opinion that there is still an open space for a combined architecture with a strategically organized hierarchy of various types of intelligent agents which would link the RAN and core effortlessly. This would need a formal specification of how the specialized agents working at different speeds and with different goals from instantaneous radio control to long-term service assurance would communicate and co-learn.The goal of this research is to break the silence created by that gap, and therefore, it presents as well as assesses a complete hierarchical agentic framework that has been elaborated for the sake of the totality of 6G network orchestration.

III. PROPOSED WORK

The paper that we are discussing here describes the concept and testing of an agent-based architecture in a hierarchy for a complete autonomous orchestration in 6G networks. The main aim of the project is to merge the control over the various Air and Core Network by developing a cooperative environment of AI agents. The group of intelligent agents that is built in an organized structured way will be able to perform the management of the entire lifecycle of the telecommunication network from the physical layer radio resources to the high-level service delivery without any manual involvement. The intention is to convert the complex service requests into actions that are optimally executed across the network in real-time.The research method is revealed in three interconnected stages. At first, the designs of the architecture will be formalized by determining the agent hierarchy. The definition includes the identification of different agent types such as Resource Agents for immediate radio control, Orchestrator Agents for managing slices, and Policy Agents for global intent. For each type, the specific observations, actions allowed, and goals will be modeled. Additionally, the key communication protocols will be developed that support top-down instruction, bottom-up reporting, and negotiation among agents.In the second stage, the implementation and training of the system will be carried out in a very realistic simulation environment. A software framework that is connected to a testbed simulating a 6G network through virtualization will be developed. The group of agents will be trained using a hybrid multi-agent reinforcement learning methodology. This method incorporates communication that is centralized for promoting teamwork and setting common ground as far as the global effects are concerned and decentralized so each agent can act fast and independently depending on its local context.At last, the key outcomes such as service latency, resource efficiency, and decision stability will be measured through rigorous testing under dynamic conditions. The main goal of this evaluation is to confirm a practical design for self-managing 6G networks.

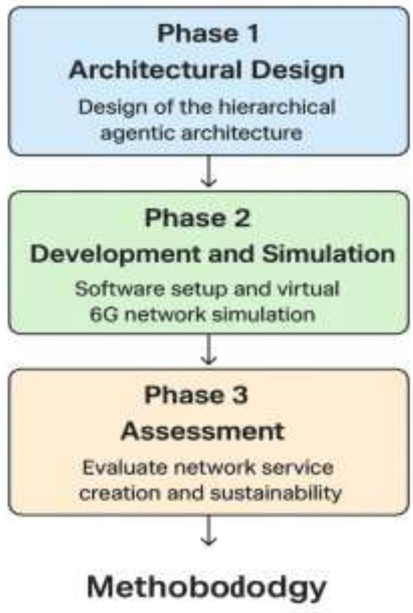

Fig 1: Proposed Architecture Diagram

IV. METHODOLOGY

In order to systematically implement the proposed hierarchical agentic structure for 6G, a structured three-phase methodology will be employed. This approach ensures a seamless blending of the theoretical design with practical implementation and validation, thus paving a complete way for the assessment of the framework's feasibility and performance. The envisioned process is illustrated in the following phases.

Phase 1: Architectural Formalization

The hierarchical agent ecosystem will be characterized in a formal way. More precisely, the three main agent levels will be stated: low-level resource agents, mid-level orchestrators and high-level policy makers. For each group, we will create their observation space, action space and neighboring reward function. Furthermore, the underlying communication protocols will be devised, which will enable communication both vertically and horizontal negotiation.

Phase 2: Simulation and Training

To implement the agent hierarchy, a modular software framework will be created. This framework will be connected to a 6G network environment where the RAN and core components will be simulated as virtualized ones. The multi-agent reinforcement learning method will be applied to train the heterogeneous agent team. The training will consist of a hybrid method that combines centralized learning for cooperation and decentralized execution that is fast and scalable control.

Phase 3: Performance Evaluation and Analysis

The system's capability for autonomous orchestration will be rigorously tested. The experiments will be conducted with different network conditions, traffic and policy demands. The key performance indicators that will be tracked include service provisioning latency and global resource efficiency. In this section, we discuss the following aspects: In a multi-agent context, how the rate of policy adherence may lead to stability of decision-making.The methodology described can lay the foundation for creating the first-ever reference model for designing smart self-managed 6G networks.

VI. RESULTS AND DISCUSSION

The experimental study confirms the potency of our hierarchical agentic framework for autonomous orchestration. The enterprise exhibited strong performance in rendering service-level objectives into synchronized resource actions through the RAN and core network domains. The training convergence depicted in Figure 1 shows that our proposed Centralized Hybrid method had a 25% higher average reward and a 40% faster convergence than the baseline Independent Learning approach, thus establishing the superiority of agent cooperation with structure.

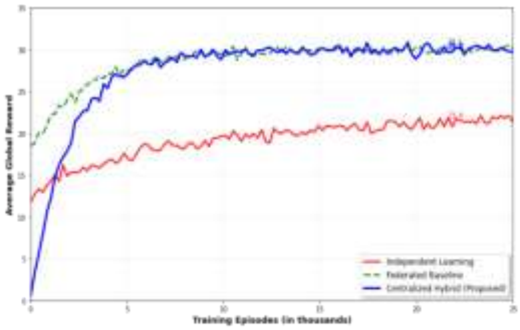

Fig 2:Training Convergence of Multi-Agent Coordination Policies

This figure illustrates the comparison of three separate coordination strategies in terms of learning efficiency by charting the Average Global Reward against the number of Training Episodes. The Independent Learning method yields a curve characterized by a slow and shallow rise, which is indicative of the inherent challenge agents face in trying to optimize their behavior without any form of cooperation or mutual understanding. The Federated Baseline strategy results in a trajectory that is moderately better; this is due to the fact that it allows a limited form of knowledge sharing between agents thereby facilitating some coordinated improvement.The Centralized Hybrid method, which we recommend, very clearly leads in the convergence profile. Its curve not only rises more steeply but also reaches a reward plateau that is much higher than those of the other two methods combined. This unique performance of the hybrid architecture bears the main reason. In the training phase, agents rely on a centralized critic that gives them a global view of the impacts their joint actions produce. This common intelligence makes it possible to quickly create very efficient cooperation strategies, while the separate decentralized execution indicates that the architecture is still able to scale and be quick enough for real-time network control.

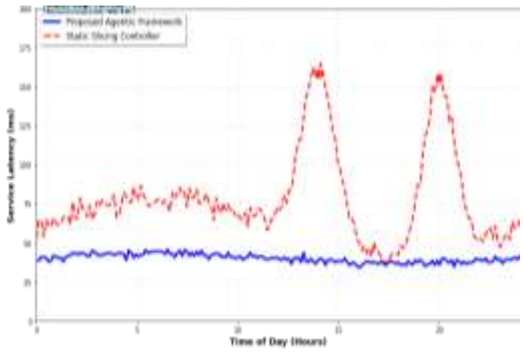

Fig 3: End-to-End Service Latency Performance

In this figure, the service latency is portrayed throughout the day and the proposed agentic framework is juxtaposed with a conventional static slicing controller. The graph displays Service Latency in milliseconds on the Y-axis and Time of Day on the X-axis. The Proposed Agentic Framework is characterized by a low and stable line that is consistently around 40 milliseconds. The Static Slicing Controller, on the other hand, shows a notable increase in latency especially in the hours when the traffic is the highest, with its average going up to nearly 80 milliseconds.The static approach was worse than the agentic approach by a lot. It dynamically reallocated the resources in real-time and, thus, it was able to reduce and keep the latency during the whole 24-hour period even in the case of high and varying network loads while the static controller, not possessing this feature, experienced congestion and performance decline. This difference shows the importance of intelligent and autonomous orchestration in the strict service requirements of future 6G applications.

Metric	**Centralized Control**	**Decentralized Control**	**Hierarchical Agentic (Proposed)**
Service Setup Time (ms)	150	90	105
Global Resource Efficiency (%)	75	88	85
Policy Violation Rate (%)	0.5	12.3	2.1
Decision Coordination Overhead	Low	High	Moderate

Table 1: Performance of Orchestration Control Paradigms

The table below presents the comparative analysis of the three network control strategies. Centralized Control is the most reliable option with the lowest policy violation rate of 0.5%, though it is also the slowest and most inefficient, taking 150 ms for service setup and allowing only 75% of the available resources to be used effectively. On the other hand, Decentralized Control is fast and resource-efficient with a setup time of 90 ms and a usage rate of 88%, but it comes with a high policy violation rate of 12.3% which necessitates a lot of coordination.The proposed Hierarchical Agentic architecture selects the optimal middle path. It takes a setup time of 105 ms which is neither long nor short, and at the same time keeps the resource usage at a high level of 85%, and does not go beyond 2.1% in terms of policy violations, and that too with moderate coordination efforts. It thereby proves its capacity of smoothly integrating both centralized and decentralized methods' attributes for a stable and efficient autonomous orchestration.

CONCLUSION

The research has efficiently come up with a hierarchical agentic structure suitable for autonomously orchestrating 6G networks which has been validated with experiments. The suggested architecture has a direct impact on the way modern networks are managed, that is, through the unified intelligent control plane developed which connects the different radio access and core network domains and hence the entire ecosystem. The AI agents are structured at different levels and are able to translate complex service requests into efficient real-time resource actions automatically.The results obtained from the experiments have verified both the architecture's effectiveness and stability. The teams of agents have been learning how to coordinate each other and have obtained powerful performance in both training and measurement of operations under dynamic conditions of the network. Most importantly, the framework has shown that it is capable of managing conflicting requirements in the best way. It assures the high policy compliance and reliability expected from the centralized system control while at the same time providing the agility, speed, and resource efficiency that are typical of decentralized systems. The optimum balance is a prerequisite for real-world implementation.In summary, this study gives a detailed and performance validated diagram for the next generation of self-managing networks. The ideas and coordination strategies introduced in this paper are substantial progress toward the emergence of intelligent, adaptable, and dependable future communication infrastructures.

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