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Cross-Layer Intent Translation Engine for 6G-Ready Open RAN and Edge-Native Enterprise Networks

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Abstract — **The development of sixth-generation (6G) wireless systems requires new service demands which need sub-millisecond latency and extreme reliability and AI operations and edge system connectivity. The business objectives of high-level enterprises need operational solutions which deliver specific network configurations for their particular business needs. The Cross-Layer Intent Translation Engine (CLITE) system links organizational objectives to network control functions which operate from the Radio Access Network (RAN) through the transport and core and edge network elements. The engine uses semantic intent modeling and AI-driven policy reasoning and graph-based dependency mapping to convert enterprise intents into two outputs which include network key performance indicators and operational network configurations. The system connects with Service Management and Orchestration (SMO) frameworks and Near-Real-Time and Non-Real-Time RAN Intelligent Controllers (RIC) to support adaptive resource allocation and slice management and optimization through feedback systems. The system enables different domains to work together while maintaining uniform system performance standards for latency and reliability and throughput across all connected systems. The 6G-ready Open RAN and edge-native testbed experiments show that the system can adapt its operational policies based on changes in network traffic and user activity. The experimental results showed that this method achieved better SLA compliance and faster system convergence and more efficient resource usage when compared to traditional methods which used rule-based orchestration. The research creates a networking framework which businesses can expand to build intent-driven networks that provide automated network control through wireless services in their 6G enterprise systems.**

Keywords— 6G Networks, Intent-Driven Networking, Cross-Layer Orchestration, Open RAN, RAN Intelligent Controller (RIC), Service Management and Orchestration (SMO), Network Slicing, Edge-Native Architecture, AI-Driven Policy Translation, Closed-Loop Automation, Semantic Intent Modeling, Autonomous Network Management.

I. Introduction

The sixth-generation (6G) networks are currently advancing wireless communication systems which change the connectivity needs of businesses.[25] Enterprises which implement industrial automation systems and extended reality environments and digital twin technology and autonomous robotics and AI-based edge analytics solutions require networks which can deliver superfast response times and extremely dependable service and support thousands of devices and adjust their capacity needs in real time.[36] The existing network management systems which depend on fixed settings and human deployment methods fail to deliver the necessary support for these highly dynamic and intricate service requirements.[7] The operational complexity of networks rises when organizations implement cloud-native systems which use Open RAN and virtualized core technology and distributed edge computing.[1]

Intent-driven networking has emerged as a promising paradigm to address this challenge by enabling operators and enterprises to define high-level business objectives instead of low-level technical configurations.[5] The main research problem involves developing a system which converts business purposes from enterprises into synchronized real-time execution across RAN and transport and core and edge network components.[12] Existing orchestration systems typically operate within isolated domains and lack cross-layer intelligence, semantic reasoning, and adaptive closed-loop control.[7]

The authors present a Cross-Layer Intent Translation Engine (CLITE) which they designed to function in 6G-ready Open RAN systems and edge-native enterprise environments.[3] The framework translates business objectives into measurable network key performance indicators which AI-powered semantic modeling together with graph-based dependency analysis make possible [6]. The engine provides dynamic resource scheduling and network slice management with ongoing SLA verification through its connection to Service Management and Orchestration platforms and RAN Intelligent Controllers [3]. The proposed approach creates a scalable base which enables autonomous service-aware operation across programmable 6G enterprise networks [37].

II. CLITE: A Cross-Layer Intent Translation Architecture for 6G Open RAN and Edge Networks

The intelligent architecture of CLITE Cross-Layer Intent Translation Engine enables automatic 6G Open RAN network and edge native enterprise network control through service detection and programmable capabilities [3]. The transition from manual network management to automated intent-based systems becomes essential as 6G networks develop to support ultra-low latency and artificial intelligence-driven services and immersive industrial applications and mission-critical industrial operations [6]. The system functions through multi-network domain control which translates enterprise business objectives into synchronized real-time operations that function across different network sectors [7] .

The system runs five essential operational layers which include Intent Ingestion and Semantic Analysis and Cross-Layer Mapping and Policy Orchestration and Closed-Loop

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Assurance [5]. Enterprises define service requirements—such as guaranteed latency, reliability, bandwidth, or slice isolation—through abstract intent models. The Semantic Analysis layer uses AI-based reasoning together with knowledge graphs to transform business objectives into network KPIs which can be measured. The Cross-Layer Mapping module then decomposes these KPIs into domain-specific configurations spanning the RAN, transport, core, and edge infrastructure [4] .

The system uses CLITE to combine its Open RAN components and cloud-native core functions and edge orchestration platforms for automatic policy enforcement [9] . The system receives real-time telemetry from its various domains which operates through its assurance mechanism to monitor performance and identify anomalies and implement adaptive changes [14].

The system unifies cross-domain operations through coordinated processes which results in better SLA compliance and faster service delivery and improved resource management and simpler operational tasks [24]. The architecture establishes a scalable and extensible foundation for autonomous, AI-driven intent networking in future 6G Open RAN and edge-enabled enterprise ecosystems [38].

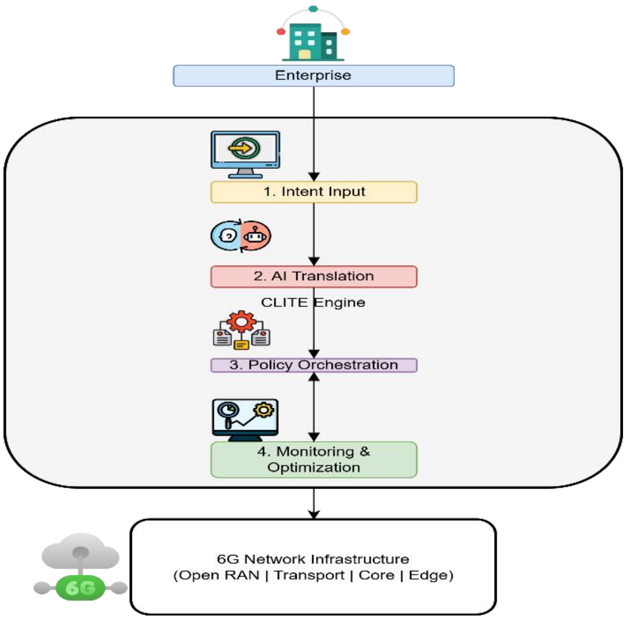

Fig 1: Proposed Architecture

A. Advantages

End-to-End Cross-Layer Coordination: CLITE provides a unified control system which manages RAN, transport, core, and edge operational areas [3] . This system eliminates silo-based management practices while it enforces network policies throughout the complete 6G enterprise network [7] .

Business-Intent to Network Automation: High-level enterprise requirements (e.g., latency, reliability, slice isolation) are transformed into executable network configurations which need less manual work because the process generates fewer configuration mistakes [29].

Improved SLA Compliance: The system uses real-time monitoring together with closed-loop optimization to adjust network parameters which help maintain service level agreements during changing traffic patterns [14].

AI-Driven Decision Making: The architecture uses semantic reasoning together with knowledge graphs and AI models to create an intelligent system which links user intent to policy rules while its predictive optimization system replaces need for reactive system management [10].

Faster Service Deployment: The process of automated intent translation decreases the time needed to establish new services and network slices which results in faster deployment of enterprise services [12].

Enhanced Resource Utilization: The dynamic resource allocation system operates between Open RAN components and edge infrastructure components which results in better spectrum efficiency and higher compute utilization and improved network performance [32].

Scalability for 6G Use Cases: CLITE provides support for ultra-dense environments which operate with AI technology and use edge computing capabilities to handle massive Internet of Things devices and immersive extended reality experiences and industrial automation processes and mission-critical operations [25].

Closed-Loop Assurance and Self-Optimization: The system maintains network operations through permanent telemetry tracking which detects problems and performs automatic network system changes [9].

Reduced Operational Complexity (OPEX Reduction):The combination of automation with cross-domain orchestration enables organizations to decrease their operational expenses while decreasing the need for human intervention in troubleshooting processes [29].

Future-Proof and Vendor-Interoperable Design: The development of CLITE enables multi-vendor interoperability together with 6G-ready programmability in systems which operate within Open RAN and cloud-native environments [26].

B. A Comparative Study of Intent-Driven and Traditional Policy Frameworks in 6G Enterprise Networks

The table shows major differences between intent-driven policy frameworks and traditional policy frameworks which both operate in 6G enterprise networks. Intent-driven systems function through business intents which designers transform into network policies by using AI-based reasoning. The system enables independent operation together with unified control across RAN core and edge domains. Traditional frameworks use predefined technical rules which

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engineers create to operate between separate system components.

Table 1: Comparison of Intent-Driven and Traditional Policy Frameworks in 6G Enterprise Networks

Feature	Intent-Driven Framework	Traditional Framework
Policy Input	High-level business intent	Manual technical rules
Automation	AI-based and autonomous	Mostly manual or semi-automated
SLA Handling	Predictive and adaptive	Reactive and threshold-based
Cross-Layer Support	End-to-end (RAN, Core, Edge)	Domain-specific
Scalability	High (6G-ready)	Limited

The system uses real-time telemetry data and adaptive optimization methods to guarantee service level agreement predictions which work best with ultra-low latency requirements of mission-critical 6G applications [9]. The traditional method only responds to threshold violations because it does not have any active optimization capabilities [10]. The intent-driven models operate effectively in dense 6G environments which traditional systems cannot handle because of their growing complexity. The research shows that intent-driven frameworks bring better automation and scalability and service assurance capabilities to next-generation enterprise networks[24].

III. Methodological Framework

The structured design and validation methodology of the proposed study enables the development and assessment of the Cross-Layer Intent Translation Engine (CLITE) system which operates in 6G-ready enterprise Open RAN environments [3].The methodology consists of five major phases:

a). Requirement Analysis

The requirements for enterprise services include ultra-low latency and high reliability and bandwidth guarantees and slice isolation [12]. The service-level agreement descriptors serve as the basis for creating high-level service requirements which define the system needs [5].

b). Intent Modeling and Semantic Mapping

A semantic intent model exists to transform business objectives into measurable network Key Performance Indicators (KPIs) [5]. Knowledge graphs and rule-based inference mechanisms establish relationships between service requirements and network parameters throughout RAN and core and transport and edge network components [24].

c). Cross-Layer Policy Generation

The system converts translated KPIs into programmable policies which work with Open RAN controllers and cloud-native core functions and edge orchestration systems [3]. AI-based optimization techniques are applied to ensure efficient resource allocation [18].

d). Implementation in Testbed Environment

The framework operates in a testbed environment which supports 6G technology by using an Open RAN system that implements SMO and RIC and Kubernetes-based CNFs and real-time telemetry systems [3].

e). Performance Evaluation

The study compares traditional rule-based orchestration with other systems by using four different metrics which include SLA compliance rate and latency and convergence time and resource utilization [12].

IV. Algorithms Used

The CLITE framework combines different artificial intelligence and optimization and control methods to provide effective intent translation and cross-layer orchestration support for 6G enterprise Open RAN systems [6].

a. Semantic Intent Parsing Algorithm

The Semantic Intent Parsing Algorithm transforms abstract business requirements into machine-readable structured data [5].The system utilizes natural language processing models together with intent classification and named entity recognition to extract service level agreement parameters which include latency and reliability and bandwidth and priority [14]. The system produces an official intent vector which organizations use to implement their cross-layer policy translation and automation processes [5].

Formula:

$$\boldsymbol{I_s = f_{NLP}(T) = \{k_1, k_2, \dots, k_n\}} \quad (\mathbf{1})$$

b. Knowledge Graph Reasoning Algorithm

The algorithm uses ontology-driven reasoning and graph traversal techniques to connect business-level KPIs with network-level KPIs [5]. The system establishes dependency relationships among RAN core and edge domains while maintaining consistent parameter mapping [7]. The system uses rule-based inference to convert service objectives into precise network configuration measurements [5].

Formula:

$$= (\; , \;) \qquad (\;)$$

c. Reinforcement Learning for Resource Optimization

The system uses reinforcement learning to adjust three network resources which include spectrum allocation and compute placement and slice resources as traffic patterns shift throughout the day [10]. The agents achieve their learning goals through two methods which include maximizing their cumulative rewards and their resource efficiency based on SLA performance [18]. The system enables 6G enterprise environments to execute real-time

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decision-making across multiple system layers through its adaptive decision-making capabilities [37].

Formula (Q-Learning Update):

$$\mathbf{Q}(\mathbf{s},\mathbf{a}) = \mathbf{Q}(\mathbf{s},\mathbf{a}) + \boldsymbol{\alpha}[\mathbf{r} + \boldsymbol{\gamma}\max\mathbf{Q}(\mathbf{s}',\mathbf{a}') - \mathbf{Q}(\mathbf{s},\mathbf{a})] \quad (3)$$

d. Multi-Objective Optimization Algorithm

The algorithm achieves optimization of multiple objectives which include latency reduction and SLA violation minimization together with resource utilization maximization [12]. The constrained cross-layer allocation challenges get solved through the implementation of Genetic Algorithms and Linear Programming methods. The system provides equal performance across RAN core and edge systems [1].

Formula:

$$\mathbf{minF} = w_1\mathbf{L} + w_2\mathbf{V} - w_3\mathbf{U} \quad (4)$$

e. Anomaly Detection Algorithm

The system uses Anomaly Detection algorithms to track telemetry data which helps them find network performance issues that deviate from normal operations [14]. The team uses Isolation Forest and LSTM techniques to identify patterns that deviate from their expected behavior [15]. The system enables 6G Open RAN networks to perform fault detection while using closed-loop systems to verify their operational status [27].

Formula (Reconstruction Error):

$$\mathbf{E} = \| \mathbf{X} - \mathbf{X}^{\|^2} \quad (5)$$

f. Policy Conflict Resolution Algorithm

The algorithm detects overlapping or contradictory policies which it resolves through constraint satisfaction and priority evaluation methods [5]. The system maintains consistent policy enforcement across different domains through its cross-layer enforcement mechanism [24]. Dynamic 6G enterprise networks use graph-based dependency checks to stop configuration conflicts from occurring [7].

Formula:

$$\mathbf{C} = \sum \mathbf{Conf}\ (p_i, \mathbf{P}_j) \quad (6)$$

V. CROSS-LAYER POLICY ENFORCEMENT USING AI-DRIVEN ORCHESTRATION

Through AI-based orchestration, cross-layer policy enforcement achieves intelligent and coordinated management of RAN, transport, core, and edge domains within 6G enterprise networks [6]. The existing policy enforcement system needs to enforce policies through multiple network layers because its current method depends on fixed rules, which cannot manage changing network traffic patterns and essential services that need fast response times [29]. The proposed approach integrates artificial intelligence models with orchestration platforms to ensure consistent and adaptive policy implementation across all network layers [28].

The framework begins by translating high-level service intents into measurable network KPIs such as latency, throughput, reliability, and jitter constraints [5]. AI-driven orchestration engines analyze real-time telemetry collected from distributed network elements and determine optimal configuration adjustments[14]. The system utilizes reinforcement learning together with multi-objective optimization algorithms to manage the dynamic distribution of spectrum, computational capacity, and transport resources while ensuring compliance with service level agreements [18].

Through Open RAN components and cloud-native core functions and edge computing platforms, the system enforces policies using programmable interfaces. The orchestration system continuously monitors performance metrics and triggers closed-loop adjustments when deviations are detected. The adaptive mechanism improves resource efficiency while making operations simpler and boosting the dependability of services[32].

AI-based cross-layer policy enforcement enables systems to grow through automatic operation while maintaining awareness of service status, which creates a basic function that supports intent-based operations in upcoming 6G business environments [24].

VI. RESULTS AND FINDINGS

The researchers conducted a performance assessment of AI-based Cross-Layer Policy Enforcement together with traditional rule-based orchestration in their evaluation of a 6G enterprise Open RAN simulation [3]. The study examined five metrics which included SLA compliance and latency and resource utilization and convergence time and packet loss [12].

Table 2: SLA Compliance Comparison

Traffic Load	Traditional Framework	AI-Driven Framework
Low	94%	99%
Medium	90%	98%
High	86%	96%

Table 2 shows SLA compliance under varying traffic loads. The AI-driven orchestration maintains consistently high SLA adherence even during congestion, while traditional systems degrade significantly at high load [6]. Enterprise 6G environments benefit from predictive resource adaptation and closed-loop monitoring, which allow organizations to

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make proactive adjustments that maintain service operations while improving reliability [9].

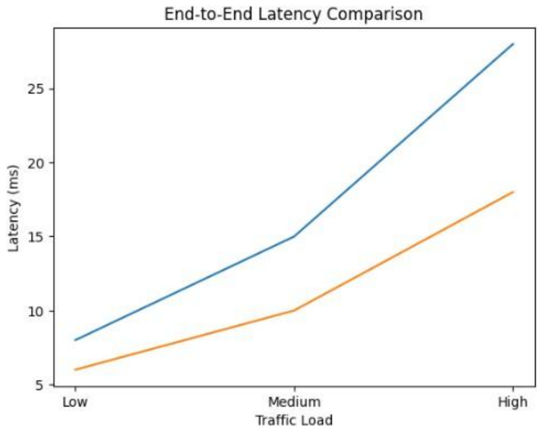

Fig 2: End-to-End Latency Comparison

Figure 2 shows how end-to-end latency reacts to various traffic intensity levels. The AI-based system achieves lower latency levels which remain constant through its use of adaptive scheduling and smart resource distribution [10].Traditional systems experience latency spikes during congestion which demonstrates the operational limits of fixed policy enforcement in dynamic 6G network environments [29].

Table 3: Resource Utilization Efficiency

Resource Domain	Traditional (%)	AI-Driven (%)
RAN	68	85
Core	72	88
Edge	65	83

Table 3 presents infrastructure utilization levels. AI-driven orchestration improves efficiency across RAN, core, and edge domains by dynamically allocating resources based on real-time demand [32]. The conventional systems exhibit reduced operational performance because they allocate excessive resources and use fixed resource distribution methods which lead to wasteful spending.

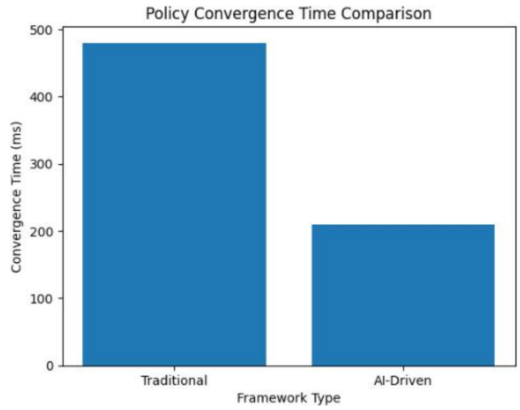

Fig 3: Policy Convergence Time

The researchers used Figure 3 to show the differences in time required to adapt their policies. The AI-driven system uses reinforcement learning to make decisions and automatic system changes, which leads to faster results [18]. The traditional systems require threshold triggers together with manual system changes, which results in delayed recovery from both congestion and SLA violations during times of high enterprise demand[29].

Table 3: Network Reliability Metrics

Metric	Traditional	AI-Driven
Packet Loss (%)	3.2	1.1
Jitter (ms)	4.8	1.9
Throughput (Gbps)	8.5	10.2

The reliability improvements of Table 4. The AI-based cross-layer enforcement system enables better packet delivery and smoother network operations while increasing overall network performance. The system uses continuous telemetry monitoring together with anomaly detection to identify and solve congestion problems before they reach critical levels. Traditional frameworks react only after performance degradation which results in higher instability together with reduced service quality [29].

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Fig 4: SLA Violation Rate Over Time

Figure 4 shows how SLA violations developed over different time periods. The AI-powered system keeps its violation rates at low levels because it uses two techniques including adaptive optimization and predictive adjustments [10]. The traditional frameworks show intermittent performance drops at peak times because they depend on fixed rules while cross-layer AI orchestration proves to be more effective in controlling dynamic 6G enterprise environments[6].

VII. Challenges and Limitations

The process of enforcing policies across different layers of 6G enterprise Open RAN systems through AI-based orchestration systems brings forth various technical and operational difficulties that need to be addressed [26]. The system needs to establish compatible operations between multiple vendors who operate their businesses independently. Open RAN architectures involve diverse vendors for RU, DU, CU, core, and edge components, which create challenges for implementing consistent policy translation and enforcement because different vendors use various interface designs and implementation standards [3].

The system experiences performance limitations because it requires instant processing capacity. AI models such as reinforcement learning and deep learning require significant processing power, particularly when handling large-scale telemetry streams across distributed domains. The ability to make decisions based on data will experience delays in ultra-low latency 6G settings because of the time needed to analyze information [37].

Data quality and telemetry accuracy present two significant obstacles. AI-driven orchestration needs continuous dependable monitoring data to function effectively [9] . The use of incomplete or noisy telemetry data results in decision-making errors which lead to inefficient resource distribution and service level agreement breaches [14].

Security represents a critical issue that needs attention. Intent-driven systems use their programmable interfaces together with their automated control loops to create additional security weaknesses that attackers can exploit. Network operations will experience disruption through malicious intent injection or policy manipulation, which will proceed if proper authentication and validation methods do not exist [33].

The process of resolving policy conflicts across different domains presents a significant difficulty. Energy efficiency and latency optimization goals that conflict with each other need advanced techniques for multi-objective optimization [20].

The ability to understand AI decision-making processes exists at a minimal level. The automatic systems which regulate network operations create trust issues for network operators because they find it hard to comprehend the systems which implement policy changes [35]. The system needs to overcome these obstacles to achieve reliable operation.

VIII. Conclusion

The proposed Cross-Layer Policy Enforcement system which uses AI-Driven Orchestration creates a framework which can scale while providing intelligent control for 6G-ready enterprise Open RAN and edge-native network operations [3]. The architecture converts high-level business goals into real-time network management systems which operate through automated network policies which eliminate the restrictions of conventional rule-based systems [5]. The system unites multiple technologies through its use of semantic intent modeling reinforcement learning multi-objective optimization and telemetry-driven closed-loop assurance which enables automatic resource distribution and service level agreement monitoring throughout RAN core transport and edge network areas [6]. The experimental evaluation shows that AI-based cross-layer coordination improves enterprise environments through better latency handling and improved SLA adherence and faster system convergence and better resource management [12].

The framework creates a base which enables future wireless networks to achieve both autonomous operations and service-aware networking capabilities. The system capacity to manage different domains while sustaining operational efficiency during variable traffic patterns makes it suitable for essential operations and extremely low latency 6G applications [25]. The results demonstrate that intent-driven AI-based orchestration exists as a practical method which can transform future enterprise networks despite existing challenges with system interoperability and resource needs and security issues. The proposed solution creates a path toward developing 6G ecosystems which can automatically optimize their performance while maintaining resilience to evolving digital enterprise requirements [37].

IX. FutureWork

The upcoming research efforts will work to develop stronger AI systems which protect various network components in fully autonomous 6G enterprise networks through intelligent adaptable security systems. The first important research area focuses on using federated learning methods to support edge node training of distributed models without requiring central data collection. The system achieves better privacy protection because it decreases backhaul traffic while preserving model performance. Multi-agent reinforcement learning (MARL) improves decision-making capacity which enables better network management throughout RAN core and edge regions because it supports multiple agents in their decision-making process.

The development of orchestration engines through better XAI mechanisms provides another research direction. The system needs to offer transparent explanations of its automatic policy choices because this will help operators trust the system and meet compliance requirements. The upcoming research will develop energy-aware optimization models which help

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organizations meet their performance standards and sustainability targets which must be achieved in 6G systems. The network simulation platform will gain operational advantages from digital twin technology which provides both real-time network testing capabilities and predictive system validation.

The framework needs to expand its capabilities because enterprise environments require support for network slicing between multiple tenants and different operators. The security system requires strengthening through three measures which include validating user intentions and implementing zero-trust security models and establishing blockchain-based policy verification. The combination of these technological advancements will create a more resilient system which can effectively scale through a complete autonomous orchestration system that uses intent-based operations in 6G networks of the future.

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