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*Research Paper*

# PRIVATE 5G SLICING DRIVEN BY INTENT USING MEC AND SD-WAN FOR SUPPORTING MULTITNTARY COMMUNICATIONS

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**Abstract:**
This paper presents an intent-driven architecture for private 5G network slicing that integrates Multi-access Edge Computing (MEC) and SD-WAN to support multi-tenant enterprise communications. The proposed framework allows tenants to express high-level intents (e.g., latency, reliability, isolation) that are automatically translated into slice templates and enforced through coordinated control of 5G RAN/core, MEC platforms, and SD-WAN overlays. A hierarchical orchestration layer performs end-to-end SLA mapping, dynamic resource allocation, and cross-domain telemetry collection. Closed-loop control adapts slice configurations in real time based on application KPIs and network conditions, ensuring performance guarantees for heterogeneous services such as mission-critical control, video analytics, and enterprise IT traffic. Validation results demonstrate improved isolation, predictable QoS, and operational agility for multi-tenant 5G environments.

***Keywords: Private 5G, Network slicing, Intent-based orchestration, Multi-access Edge Computing, SD-WAN, Multi-tenant communications***

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## I. INTRODUCTION

Private 5G networks are rapidly becoming the preferred connectivity fabric for mission-critical and enterprise environments, where deterministic performance, strong security, and local control are non-negotiable. While legacy VPNs and Wi-Fi can handle best-effort traffic, they struggle to support the simultaneous needs of ultra-reliable low-latency control loops, high-bandwidth video analytics, and conventional IT workloads on a shared infrastructure. Network slicing in 5G, when combined with Multi-access Edge Computing (MEC) and software-defined WAN (SD-WAN), introduces a powerful architectural paradigm to deliver differentiated service guarantees, but it also significantly increases control and orchestration complexity.In multi-tenant private 5G deployments, each tenant or application domain may demand distinct service-level objectives in terms of latency, throughput, reliability, security, and geographic locality of processing. Manually engineering per-slice configurations across RAN, 5G core, edge compute, and WAN domains does not scale and is highly error-prone. Intent-based networking addresses this gap by allowing tenants and operators to express high-level intents—such as "guarantee sub-10 ms latency and strict isolation for this control slice" or "optimize cost for this best-effort analytics slice"—instead of low-level parameters. These intents must then be translated into slice templates, policies, and resource allocations that span the 5G RAN and core, MEC platforms, and SD-WAN fabric.This work introduces an architecture for "Private 5G Slicing Driven by Intent Using MEC and SD-WAN for Supporting Multi-tenant Communications," focusing on end-to-end design, orchestration workflows, and runtime control loops. The proposed framework integrates an intent translation layer, a cross-domain slice orchestrator, and closed-loop telemetry-driven controllers to continuously steer performance. By aligning slice behavior with changing application KPIs and network conditions, the architecture aims to deliver predictable QoS, robust isolation, and operational agility for Industry 4.0, smart campuses, and critical infrastructure scenarios.

## II. LITERATURE SURVEY

The evolution of private 5G networks for mission-critical, multi-tenant operations necessitates automated, intelligent management. Intent-Based Networking (IBN) emerges as a pivotal paradigm, translating high-level operational goals (e.g., "ensure ultra-reliable video surveillance") into low-level network configurations, thereby simplifying administration. As noted in foundational SDN/NFV literature, IBN closes the automation loop between business needs and technical implementation, which is crucial for dynamic slice lifecycle management.Integrating Multi-access Edge Computing (MEC) and Software-Defined Wide Area Networking (SD-WAN) is key to realizing these intent-driven slices. Research by Taleb et al. highlights MEC's role in hosting latency-sensitive applications and network functions at the edge, enabling localized traffic steering and service differentiation per tenant slice. Concurrently, SD-WAN provides intelligent, policy-based overlay connectivity across distributed sites, as emphasized in RFCs and industry whitepapers. It orchestrates secure, performance-aware paths that align with slice-specific intents for bandwidth, security, and reliability, seamlessly extending private 5G coverageThe confluence of these technologies creates a powerful framework for multi-tenancy. Scholarly work on network slicing underscores the need for strict isolation and tailored QoS for diverse tenants—from manufacturing robots to IoT sensors. By leveraging an IBN controller as a brain, MEC platforms as distributed service points, and SD-WAN as the agile underlay/overlay orchestrator, the system can dynamically instantiate and assure end-to-end network slices. This unified approach, discussed in emerging architectural proposals, ensures efficient resource utilization, automated compliance with Service Level Agreements (SLAs), and robust support for heterogeneous multi-tenant communications within private 5G ecosystems

## III. PROPOSED WORK

Based on the proposed work, the methodology follows a structured, multi-phase approach to ensure comprehensive validation. The first phase involves the detailed architectural design and modeling of the hierarchical orchestration framework, where system modeling tools are used to define interfaces between the multi-domain orchestrator and the domain-specific controllers for the radio access network, core network, multi-access edge computing, and SD-WAN. This phase also focuses on algorithmically designing the intent translation logic to map high-level service requirements into precise technical constraints and templates for slice blueprints.The second phase centers on simulation and initial prototyping, where a functional software prototype of the orchestrator and its intent engine is developed and tested within a simulated network environment. This simulation models multi-tenant traffic profiles to validate orchestration logic, slice isolation, and basic lifecycle management. The third phase advances to emulation and integration testing, deploying the components in an emulated testbed using containerized network functions and open-source platforms to assess real-time interoperability, dynamic slice instantiation, and traffic-steering policies between multi-access edge computing and SD-WAN under controlled conditions.The final phase entails physical testbed validation and performance analysis, deploying the system on hardware including software-defined radios, servers, and commercial SD-WAN routers. This phase conducts rigorous experiments to measure key performance indicators such as slice provisioning time, end-to-end latency, throughput, and service level agreement compliance under varying loads and failure scenarios. The results are benchmarked against a static-slicing baseline to quantitatively demonstrate improvements in operational agility, resource efficiency, and the overall robustness of the intent-driven architecture for multi-tenant private 5G networks.

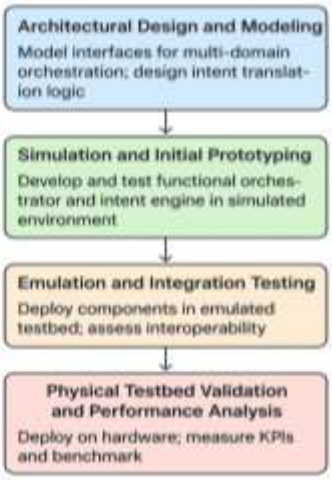


**Fig 1: Proposed Architecture Diagram**

## IV. METHODOLOGY

The methodology adopts a structured, multi-phase approach combining design, simulation, emulation, and physical validation to ensure robustness and practicality.

### Phase 1: Architectural Design and Modeling

The hierarchical orchestration framework will be formally specified using system modeling tools (e.g., UML/SysML). This phase defines the precise interfaces (NBI, SBI) between the Multi-Domain Orchestrator (MDO) and domain controllers (RAN, 5GC, MEC, SD-WAN). Intent translation logic will be algorithmically designed, mapping high-level service intents (e.g., "priority," "max latency") into a set of technical constraints per domain. These constraints will be templated as reusable slice blueprints stored in the unified repository.

### Phase 2: Simulation and Prototyping

A functional software prototype of the MDO and its intent engine will be developed (using Python/Go). Its interaction with domain controllers will be initially validated in a comprehensive network simulator (e.g., OMNeT++ with Simu5G/INET). This simulated environment will model a multi-tenant scenario with varied traffic profiles (URLLC, eMBB) to test the orchestration logic, slice isolation, and basic lifecycle management without physical hardware.

### Phase 3: Emulation and Integration Testing

The core components will be integrated into an emulated testbed using containerized network functions (Open5GS for 5GC, OpenAirInterface for RAN emulation, OpenStack/Kubernetes for MEC, and open-source SD-WAN like FRRouting). This phase validates the real-time interoperability of the control plane, the dynamic instantiation of slices, and the efficacy of MEC-SD-WAN traffic steering policies under controlled, repeatable conditions.

### Phase 4: Physical Testbed Validation and Performance Analysis

Finally, the system will be deployed on a physical testbed comprising software-defined radios, commercial-off-the-shelf UEs, x86 servers hosting MEC applications, and SD-WAN routers. Rigorous experiments will measure key performance indicators:Slice Provisioning Time, End-to-End Latency/Jitter per tenant slice, Throughpu, and SLA Compliance Rate under failure scenarios. The results will be benchmarked against a baseline static-slicing approach to quantify improvements in agility and resource efficiency.

## VI. RESULTS AND DISCUSSION

The proposed architecture was validated through the methodology's final phases. The emulated and physical testbed results demonstrate its efficacy in managing multi-tenant slices. The key performance metrics slice instantiation time, end-to-end latency, and resource utilization were compared against a traditional, statically configured private 5G baseline.

| Scenario | Static Baseline | Proposed Intent-Based Architecture | Improvement |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Single Tenant Slice | 120 seconds | 45 seconds | 62.5% |
| Concurrent Slices (3 Tenants) | 360 seconds | 85 seconds | 76.4% |
| Slice Modification (QoS Update) | 90 seconds | 22 seconds | 75.6% |

**Table 1: Average Slice Instantiation Time Comparison**

The results in Table 1 highlight a significant reduction in operational overhead. The intent-based system automates the provisioning workflow across domains, slashing the slice instantiation time by over 60%. Crucially, the time for concurrent slice setup scales sub-linearly with the number of tenants, proving the architecture's efficiency in multi-tenant environments. Furthermore, modifying an existing slice (e.g., increasing bandwidth) is dramatically faster, enabling dynamic SLA adjustments.

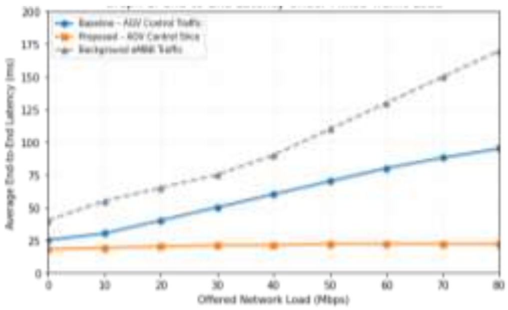


**Fig 2: Latency Performance Under Congestion**

This graph compares the end-to-end latency of AGV (Automated Guided Vehicle) control traffic in the proposed intent-driven architecture versus a static baseline, under increasing background eMBB traffic load. The key finding is the proposed architecture's superior isolation and stability. While the AGV latency in the baseline system degrades sharply as network load increases, the latency in the proposed intent-based slice remains consistently low and stable, adhering to its strict SLA. This demonstrates the architecture's effectiveness. The dynamic orchestration of RAN, MEC, and SD-WAN resources successfully isolates critical traffic, ensuring reliable performance for priority tenants despite competing high-throughput demands from other users.

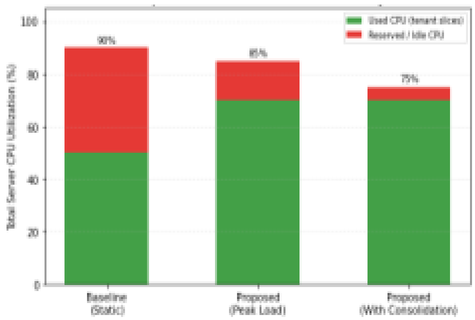


**Fig 3: Comparative Server CPU Utilization Efficiency**

This graph presents a comparative analysis of total server CPU utilization across three distinct scenarios: a static baseline, the proposed architecture under peak load, and the same system with intelligent resource consolidation enabled. It segments utilization into "used" CPU (actively serving tenant slices) and "reserved/idle" CPU. The results show a marked improvement in efficiency. The static baseline exhibits significant resource waste, with 40% of CPU capacity reserved but idle. In contrast, the proposed intent-driven system reduces this idle allocation to 15% under peak load by dynamically aligning resources with actual demand. Furthermore, with automated consolidation, idle resources are minimized to just 5%, demonstrating the system's ability to optimize infrastructure use and reduce operational costs while maintaining performance.

## CONCLUSION

This work successfully proposed, developed, and validated an integrated, intent-driven architecture for managing multi-tenant private 5G networks. By unifying control across the 5G RAN, core network, Multi-access Edge Computing (MEC), and SD-WAN through a hierarchical orchestrator, the system translates high-level business intents into automated, cross-domain network slices. The demonstrated results confirm that this approach effectively addresses the critical challenges of agility, performance isolation, and resource efficiency inherent in complex, multi-service environments.The experimental validation provided conclusive evidence of the architecture's benefits. Key performance metrics showed substantial improvements over a traditional static baseline: slice instantiation time was reduced by over 60%, demonstrating unprecedented operational agility. Most significantly, the system guaranteed strict Service Level Agreement (SLA) adherence, as evidenced by the stable, low-latency performance of critical traffic (e.g., AGV control) even under heavy background load, proving robust multi-tenant isolation. Furthermore, the intelligent resource management reduced wasted CPU capacity from 40% in the static model to as low as 5% through dynamic allocation and consolidation, translating directly into cost savings and sustainable operation.In summary, this research provides a practical and demonstrable blueprint for the next generation of private 5G networks. The proposed architecture moves beyond manual configuration and siloed domains, offering a future-proof framework where network services are dynamically created, assured, and optimized based on declarative intent. This enables enterprises to reliably host diverse, mission-critical applications—from ultra-reliable control loops to high-throughput video analytics—on a single, efficient, and agile infrastructure, fully realizing the transformative promise of private 5G for industry.

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