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Dynamic Traffic Steering for Networked Robotics Using 3GPP-Compliant Application Functions

4th GI/ITG KuVS expert discussion Network Softwarization

Content

Motivation

Collaborative visual Simultaneous Localization And Mapping (vSLAM) using real-time sensor data.

- Low-latency communication in 5G networks enables advanced applications in networked robotics.
- 5G enables high data rates, low-latency communication, and software-defined control of data and control planes.
- By utilizing Multi-access Edge Computing (MEC), robots offload compute-intensive tasks to nearby MEC servers to reduce energy consumption.
- MEC enhances scalability and responsiveness for networked robotic systems.

These capabilities make 5G and MEC jointly critical for deploying scalable and responsive vSLAM in networked robotics.

How can 5G network maintain the best service experience for networked robots due to high traffic rate?

Gerasimos Damigos et al. "Communication-Aware Control of Large Data Transmissions via Centralized Cognition and 5G Networks for Multi-Robot Map merging". In: J. Intell. Robotics Syst. 110.1 (Jan. 2024). ISSN: 0921-0296. DOI: 10. 1007/s10846-023- 02045- 4. URL: https://doi.org/10.1007/ s10846-023-02045-4.

Problem Statement

Challenge: Existing 5G traffic steering ignores MEC compute load → service congestion, degraded QoS.

Impact: Suboptimal routing for latency-sensitive apps (e.g., collaborative vSLAM in robotics).

Gap: No joint optimization of network paths + MEC resource availability.

Solution: A novel traffic steering framework that jointly considers real-time network conditions and MEC compute availability.

Our approach leverages the 3GPP-defined Application Function (AF) to optimize service instance selection, minimizing latency and improving load distribution.

3GPP. 5G; Procedures for the 5G System (5GS) (3GPP TS 23.502 version 18.8.0 Release 18). Tech. rep. 2025.

3GPP. 5G; System architecture for the 5G System (5GS) (3GPP TS 23.501 version 18.8.0 Release 18). Tech. rep. 2025

Peter Sossalla et al. “DynNetSLAM: Dynamic visual SLAM network offloading”. In: IEEE Access 10 (2022), pp. 116014– 116030. DOI: 10.1109/ACCESS.2022.3218774.

Proposed Approach

AF-based traffic steering framework.

- Real-time traffic monitoring and decision-making.
- Adaptive network policies based on robotic system requirements.

Dynamically selects MEC service instances using real-time:

1. Network conditions (latency, bandwidth).
2. MEC compute metrics (CPU, memory, queue depth).
3. AF Controller triggers PDU session modifications for optimal routing.

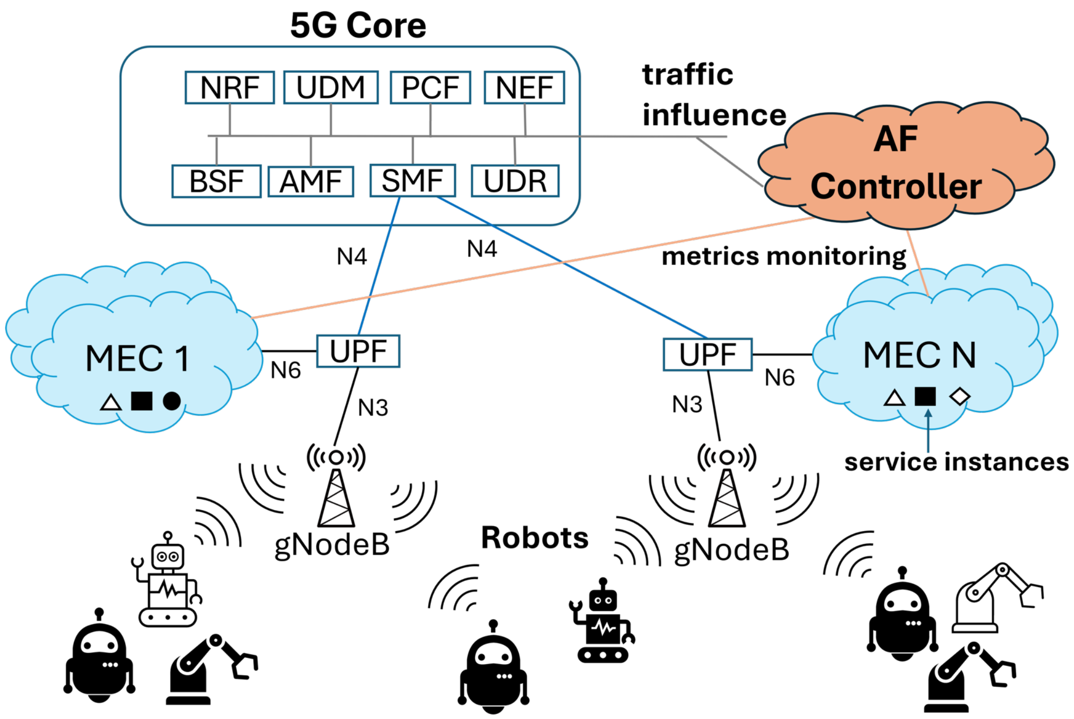

Fig. 1. Proposed system architecture – AF controller orchestrates dynamic traffic steering from UE to optimal MEC service instances.

Tran Minh Ngoc and Younghan Kim. Computing Aware Traffic Steering Consideration for Mobile User Plane Architecture. Internet-Draft draft-dcn-dmm-cats-mup-04. Work in Progress. Internet Engineering Task Force, Nov. 2024. 18 pp.

Cheng Li et al. A Framework for Computing-Aware Traffic Steering (CATS). Internet-Draft draft-ietf-cats-framework-05. Work in Progress. Internet Engineering Task Force, Feb. 2025. 26 pp.

Planned Implementation Architecture

Components:

- 5G Core (free5GC)
- MEC (Kubernetes nodes)
- AF Controller

Functionality of AF Controller:

- Monitors MEC metrics (Prometheus)
- Subscribes to SMF events
- Triggers traffic rerouting via traffic influence procedure to SMF for PDU session modification

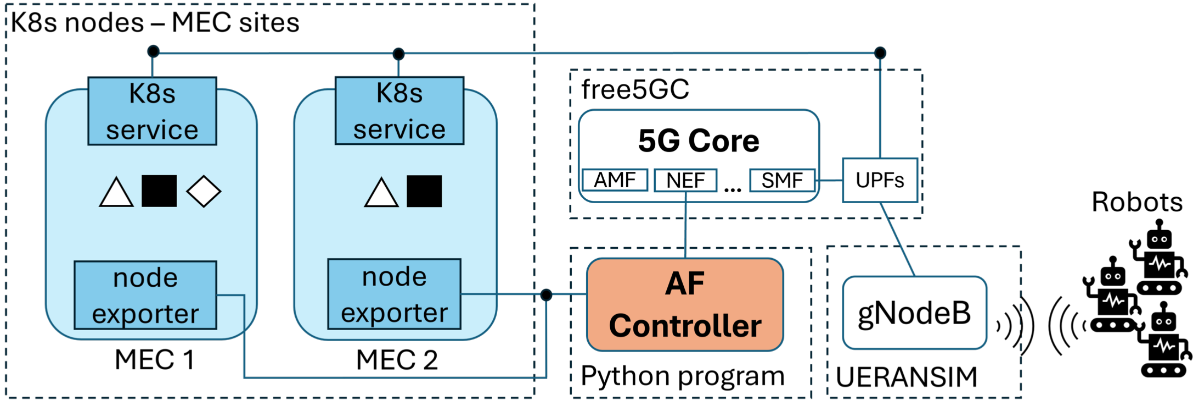

Fig. 2. Testbed design for implementation and evaluation.

Evaluation Methodology

1. **Metrics Evaluated:**
   - Roundtrip Time (RTT): Measures request-response delay.
   - PDU Session Modification Latency: Tracks time to redirect traffic to an optimal service instance.
   - AF Traffic Influence Rule Creation Time: Assesses delay in generating and enforcing traffic influence rules to the 5G Core.
2. **Benchmarked Algorithm:**
   - Heuristic method assessing CPU & memory usage (threshold: 70%) → *Optimization is left for future work.*
3. **Traffic Generation:**
   - UEs send continuous traffic, MEC nodes validate selection efficiency.
   - AF uses Prometheus APIs for optimal instance selection.
4. **Service Instance Computing Status:**
   - AF monitors MEC load and dynamically steers traffic.

Hypothesis

Without our approach:

- Increasing traffic degrades service experience due to suboptimal service selection
- Standard 5G lacks dynamic PDU session modifications based on MEC resource status

With our approach:

- Ensuring optimal performance.
- Our solution enables AF to adjust sessions when latency increases

Broader Impact:

1. Standard-aligned: 3GPP Release 18 → Future-proof (6G).
2. Applications:
   - Industrial automation
   - Swarm robotics

Summary and Future work

Summary:

1. Novel 5G traffic steering framework optimizes service selection by considering network and MEC conditions.
2. Our approach leverages AF to route traffic efficiently, minimizing latency and improving service quality.

Future work:

1. Refine method details, evaluation plan, and a 5G-enabled testbed for future adaptability
2. Report hypothesis and evaluation results

Thank you!

Q & A