

Executive Summary

Objective: Develop a communication-aware swarm coordination framework that integrates ROS 2 robotics middleware with O-RAN infrastructure using the ORANSlice platform.

Key Innovation: RL-based intelligent scheduling xApp that dynamically maps robotic mission requirements to network slicing configurations in real-time.

Impact: Enables Ultra-Reliable Low-Latency Communication (URLLC) for mission-critical multi-robot applications with guaranteed QoS.

Background

Challenge	Traditional WiFi	Our O-RAN Solution
Latency	Unpredictable (10-100ms)	<1ms target (URLLC)
Reliability	Best-effort, congested	Guaranteed QoS via slicing
Scalability	Limited (interference)	Dynamic RAN slicing
Mobility	Poor handoff performance	Predictive RL-based handoffs

The Challenge: Traditional Wi-Fi and ad-hoc mesh networks fail to provide ultra-low latency and high reliability needed for safety-critical robotic swarms. Current systems treat the network as a passive "black box," creating performance bottlenecks.

The Solution: O-RAN disaggregates network functions, allowing for **application-specific management**.

The Need: Transitioning swarm systems from being merely network-tolerant to **network-aware** is essential for Industry 4.0 and disaster response.

Experimental Setup

- **Robots:** AgileX LIMO mobile robots equipped with **NVIDIA Jetson AGX Orin**.
- **Sensors:** YDLIDAR Tmini Pro (Model Code 150) for real-time laser scanning.
- **Network:** OAI-based gNodeB (gNB) using the **ORANSlice** framework and **USRP B200/B210** hardware.
- **Software Stack:** Ubuntu 22.04, **ROS 2 Humble**, and OpenAirInterface (OAI) 5G protocol stack.



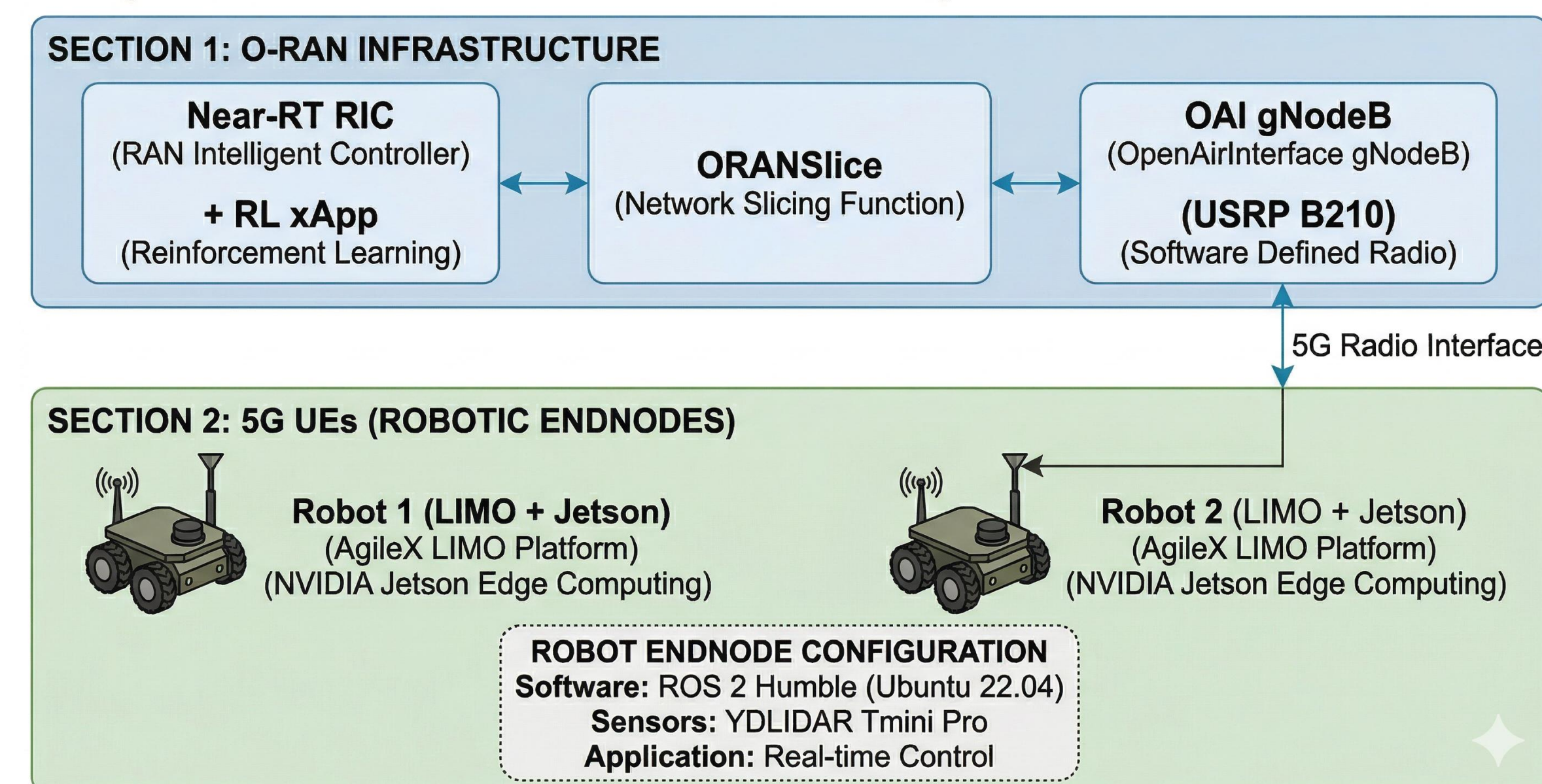
Figure 1: Testbed setup showing three mobile robots used for swarm coordination

Experimental Test Plan

Our framework integrates the robotic control loop with network resource allocation through three innovations:

- 1. Bi-directional Information Flow:** A robust interface between **ROS 2** and the O-RAN Near-RT RIC allows robots to report task priorities while receiving QoS feedback.
- 2. Intelligent Slicing xApp:** An **Reinforcement Learning (RL)** agent monitors network and kinematic states (latency, SNR, velocity) to adjust slice bandwidth and priority weights in real time.
- 3. Resilient Fallback:** When connectivity is lost, robots switch to **peer-to-peer relaying** and local RL-trained decision-making.

Figure 2: Architecture for O-RAN Enabled Slicing and Control of Mobile Robots



Experimental Results

UDP Transfer Performance vs. Chunk Size

We evaluated the **Peak Signal-to-Noise Ratio (PSNR)** of LiDAR data transmitted over different network configurations to find optimal throughput.

Chunk Size	Loss Rate	PSNR (dB)	Result
64 Byte	2.49%	14.64 dB	High overhead
128 Byte	1.92%	14.64 dB	Optimal for USRP B210
256 Byte	1.98%	14.64 dB	Systemic bottleneck
512+ Byte	2.22%+	14.64 dB	Critical Loss

- **Static Objects:** Achieved **"Excellent"** quality (inf dB PSNR) over both Wi-Fi and Ethernet for 60-second static scans.
- **Dynamic Objects:** Maintained **"Excellent"** quality with 97.2% frame alignment over Wi-Fi, even with significant time offsets.
- **Signal Strength:** Recorded consistent signal strength measurements at distances ranging from 3m to 9.4m to establish baseline performance.

Conclusions

Achievements:

- End-to-end integration of ROS 2 robots with O-RAN testbed
- Validated URLLC performance for multi-robot coordination
- Optimized USRP B210 transmission parameters
- Demonstrated perfect data fidelity over Ethernet/WiFi

Next Steps:

- Deploy RL xApp on Near-RT RIC for real-time slicing decisions
- Conduct multi-cell handoff experiments with mobility
- Implement peer-to-peer fallback during outages
- Scale to 4+ robot swarm with obstacle navigation

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References

- [1] M. U. Farooq, M. Waseem, S. Mazhar, M. Khanzada, and E. Ahmed, "A survey on 5g and beyond for smart cities: Progress, challenges, and opportunities," *Sensors*, vol. 21, no. 18, p. 5992, 2021.
- [2] M. Polese, L. Bonati, S. D'Oro, and T. Melodia, "Understanding O-RAN: Architecture, interfaces, algorithms, security, and research challenges," *IEEE Communications Surveys & Tutorials*, vol. 24, no. 1, pp. 1–29, 2022.
- [3] H. Cheng et al., "ORANSlice: An open-source 5G network slicing platform for O-RAN," in *Proc. ACM MobiCom*, Washington, D.C., 2024.