dfki ai Deutsches Forschungszentrum für Künstliche Intelligenz
German Research Center for Artificial Intelligence

Advancing Telerobotics: Evaluating ROS 2 in a Real-World Communication Test Environment

29. Fachtagung Mobilkommunikation
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Agenda

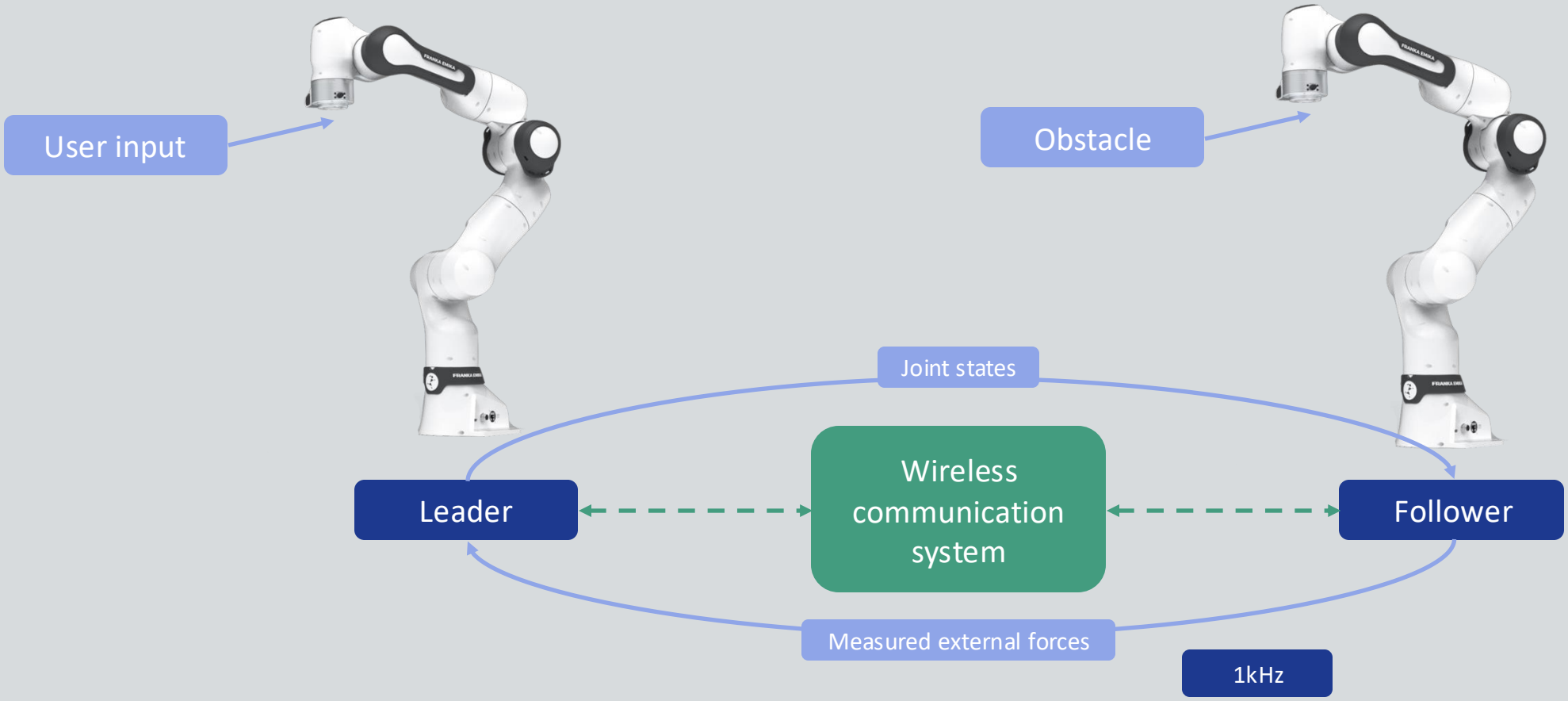
- Motivation
- Environment Setup
- Performance Analysis
- Conclusion and Outlook

Motivation

- Wireless robotic teleoperation is increasingly relevant
- Real-time applications are sensitive to latency and jitter
- Real-world test environments provide valuable insights
- Previous version based on ROS (1)
  - Limitations in real-time capability and scalability
  - EOL: 31st May[1]
- Updated version using ROS 2

[1] http://wiki.ros.org/Distributions

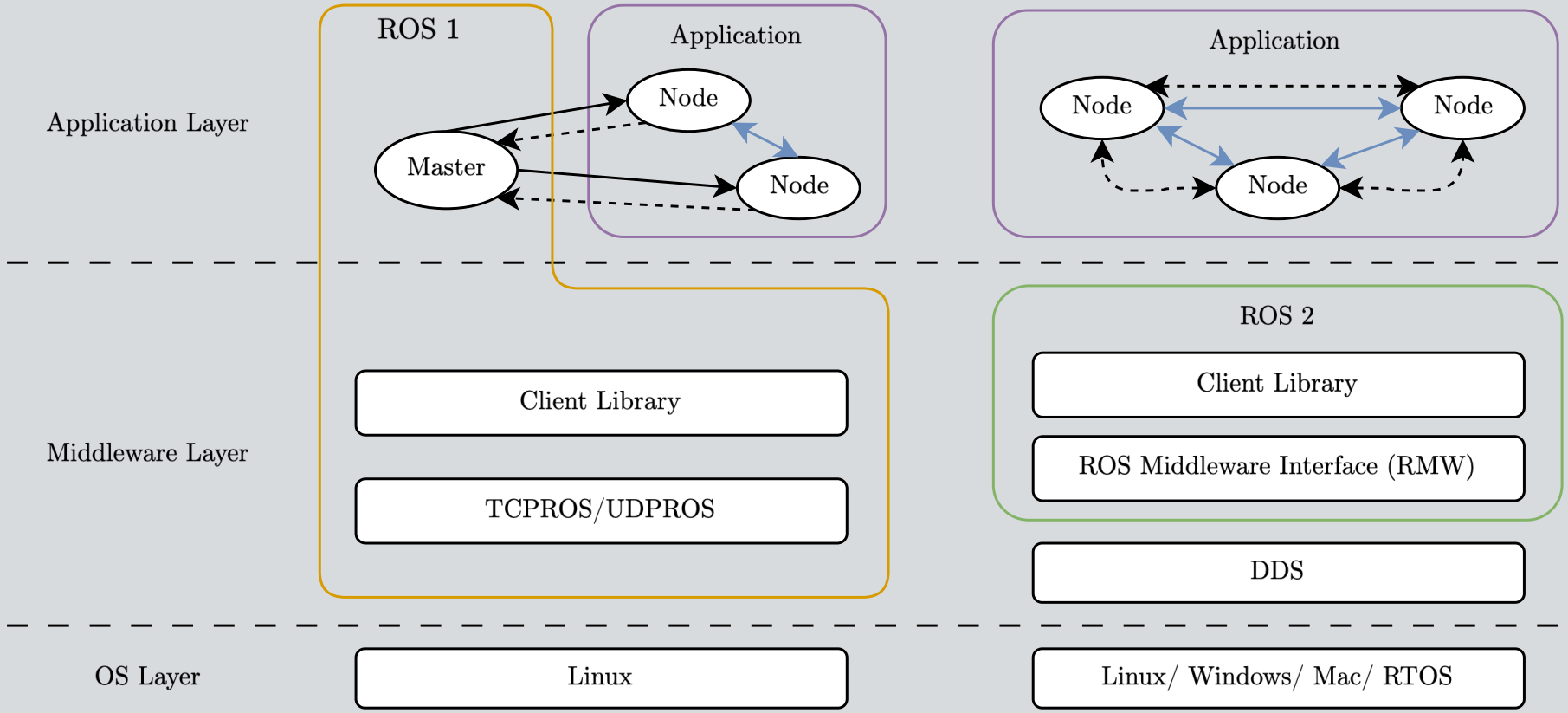
Environment Setup: Overview



Environment Setup: Overview

- Host systems: Debian 12.8, real-time kernel 6.1.0-27-rt
- ROS environments containerized
  - ROS 1 (Noetic): Ubuntu 20.04
  - ROS 2 (Humble): Ubuntu 22.04

Environment Setup: Differences ROS 1 and ROS 2



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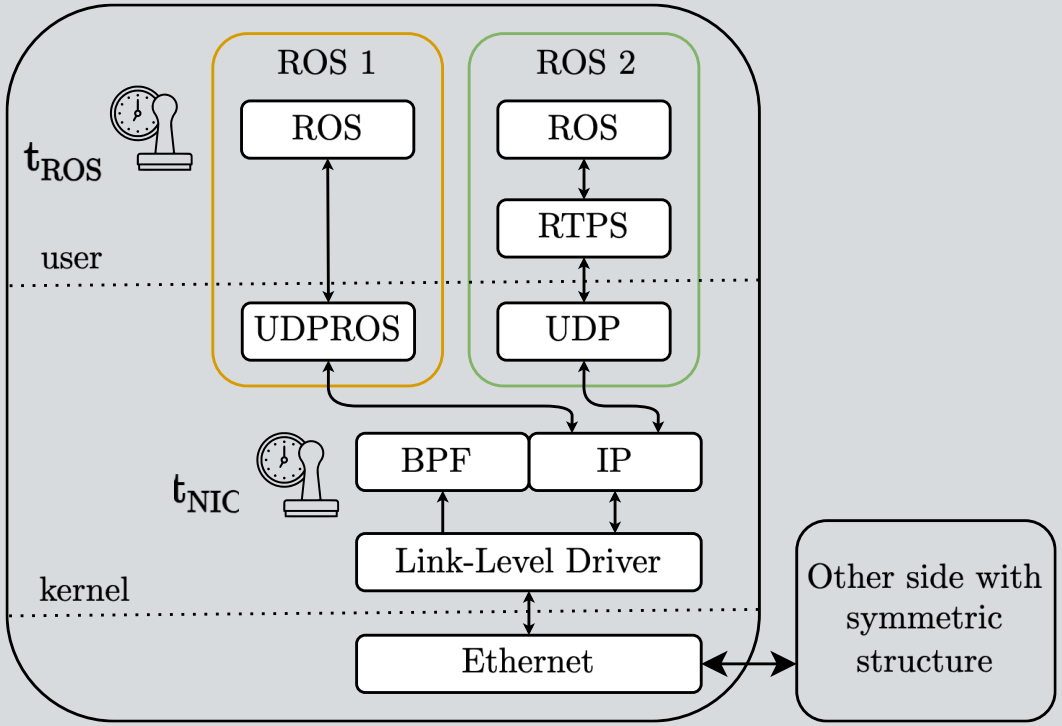
Environment Setup: Differences ROS 1 and ROS 2

- Robot hardware access modularized
- Enhanced flexibility in parameter management
- Python-based launch scripts
- Lifecycle management

Environment Setup: Further Code Modifications

- Controller state
  - ROS 1: based on list of active nodes
  - ROS 2: lifecycle nodes monitoring state transitions
- Motion scaling
  - Via Inverse Kinematics before publishing joint state
  - Scales along Cartesian x and y axes

Environment Setup: Measurement Methodology

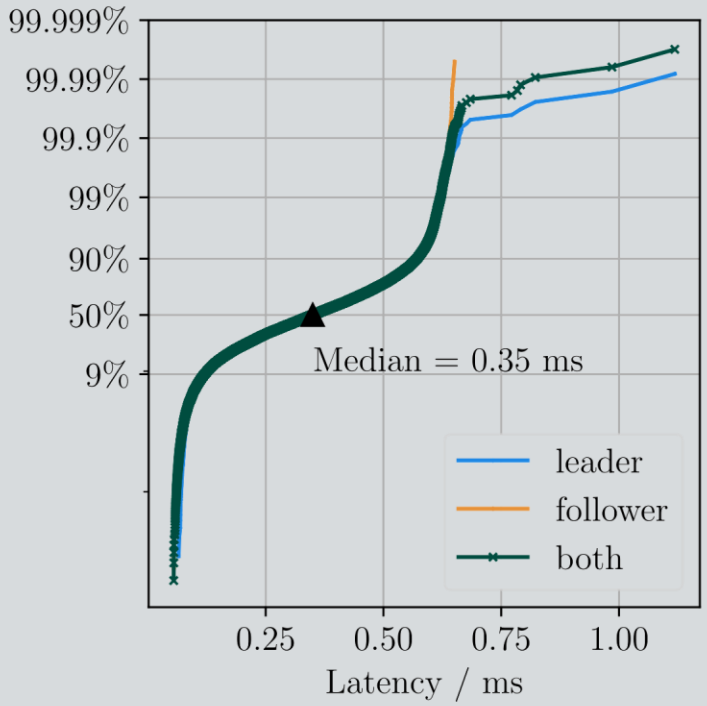


$$d_{total} = t_{\mathrm{ROS\_RX}} - t_{\mathrm{ROS\_TX}}$$
$$d_{tx} = t_{\mathrm{NIC\_TX}} - t_{\mathrm{ROS\_TX}}$$
$$d_{n} = t_{\mathrm{NIC\_RX}} - t_{\mathrm{NIC\_TX}}$$
$$d_{rx} = t_{\mathrm{ROS\_RX}} - t_{\mathrm{NIC\_RX}}$$

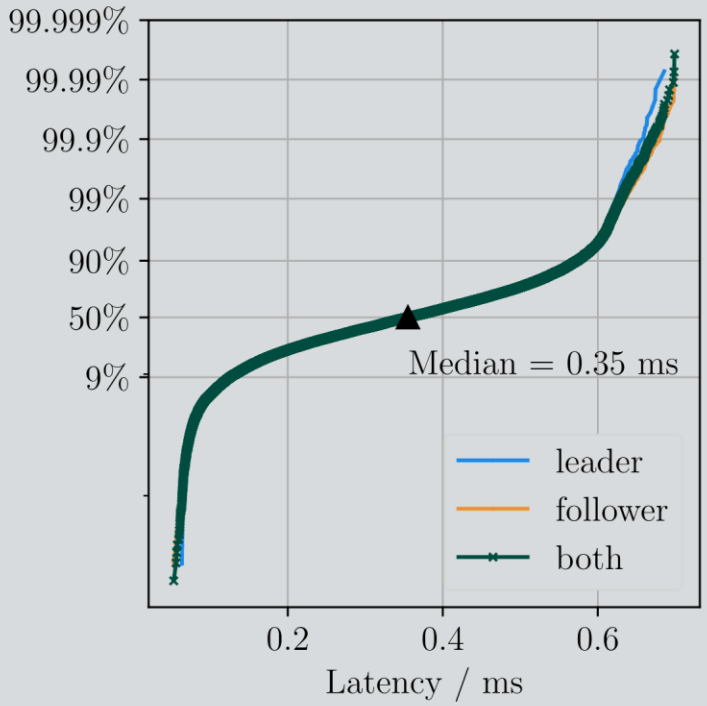
Performance Analysis: Overview

- Ethernet connection as baseline
- Reliability metrics: latency probability bounds
- Analysis of over 200,000 packets

Performance Analysis: End-to-End Latency



ROS 1



ROS 2

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Performance Analysis: End-to-End Latency

ROS - ROS

	median/ms	2-9s/ms	3-9s/ms	4-9s/ms	jitter/%
ROS 1	0.351	0.816	1.714	1.967	55.75
ROS 2 w/o IK	0.350	0.698	0.699	0.699	55.01
ROS 2 w IK	0.350	0.695	0.699	0.699	55.02

LBPs

NIC - NIC

	median/ms	2-9s/ms	3-9s/ms	4-9s/ms	jitter/%
ROS 1	0.032	0.076	0.098	0.100	10.5
ROS 2	0.020	0.039	0.042	0.042	7.71

Performance Analysis: Real-Time Capability

	value	mean/ms	std/ms	max/ms
ROS 1	inter-departure time	1.606	0.444	4.062
	inter-arrival time	1.606	0.497	3.849
ROS 2	inter-departure time	1.000	0.036	1.432
	inter-arrival time	1.000	0.239	1.788

Conclusion and Outlook

- Evolution of robotic teleoperation test environment
- Comparison between ROS 1 and ROS 2
- Substantial performance gains
  - Lower maximum end-to-end latency and jitter
  - More consistent publishing/ subscribing intervals
- More robust and modular testbed with improved real-time capabilities
- Integration with ROS 2 Jazzy
- Extensive field trials
  - Systems of project partners
  - 5G Campus network
  - Commercial cellular networks

Thank you

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