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We know Autonomous Towing Robots



Keshav CEO and Lead Clients and Solutions PhD, Space Robotics

12 yrs space Industry > 1MEUR ESA grants R&D consultant @imec > 1.5MEUR H2020 funds



Geert Lead Machine Design >35 years deep expertise

Creative machine builder Many machines in wild **Elias Lead** Systems Engineering PhD, AI and Robotics

8 years R&D Robotics/Al Cloud and networking

Rishabh SaaS Engineer Half-time (India)

Wim IT/Systems Consultant Part-time

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Robotics-as-a-Service Benchmarks over ROS2 Phase 2 (RaaS-o-ROS2)

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Industry-grade omni-directional AMRs

Intelligent navigation with APIs

Task execution in the worst wireless networks

OMNIT Autonomous Mobile Robot

Tractonomy

1853

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Secure Cloud Fleet Management



Dynamic fleet discovery and control in the cloud



Connectivity in the worst wireless networks



Enabling lease models for remote maintenance and support



Enabling pay-per-tow and other service driven revenue models









RaaS Requirements

Fast

Secure

Scalable





Robotics-as-a-Service with ROS2

ROS1 originally a research framework

Quickly penetrating industrial robotics

ROS1 was never designed for networking

ROS2 -> next gen middleware for robotics

- + Data Distribution Service (DDS) specification
- + Real-time Publish Subscribe (RTPS)

+ robust security policies



Image courtesy: G. Mazzeo, "TROS: Protecting Humanoids ROS from Privileged Attackers", 2019, International Journal of Social Robotics,



Phase 2 Objectives



SROS2

Deploy Tractonomy RaaS architecture and scale AMR components with secure ROS2 on Fed4Fire testbeds

Design and implement the system QoS tool (sQoS) tool to benchmark ROS2 middlewares (RMW) and ROS2 QoS settings

Benchmark RaaS platform using sQoS tool

- Scalability (fleet)
- Compare performance metrics of different RMW implementations
- Reevaluate failures of phase 1



Client

Site 1

Technical Implementation

Iterate and identify the idea sQoS

5. Measure sQOS



sQoS Tool configured through environment variables available in an experiment file. Multiple experiments can be launched at the same time by providing multiple files.

Containers are configured during start-up.

sqos_tool.sh [options] EXPERIMENT_FILE...

- -i interface:
- -s all|loss|delay|non

-r #:

interface to apply traffic shaping to (default: lo) traffic shaping to perform (default: none) times to repeat experiments (default: 1)



Fed4Fire Testbeds

VirtualWall2 - For entire architecture deployment with a cloud server, a site manager and multiple workers possible of each running upto 10 AMR simulations

Grid'5000 - initial multi site tests

Emulab Utah - test case for multi site deployment on bare-metal systems with one site manager and a worker running upto 2 AMR simulations note: single test runs work but repeated tests failed to discover the Docker Swarm node.

ExoGENI - second test case for multi site deployment on virtual machines with one site manager and one worker running a single AMR simulation







Results

Performance metrics of RMW implementations while scaling the number of connected AMRs



ROS2 default RMW performance degrades as the number of AMRs increase (ROS2 nodes). Cyclone DDS has an overall better performance.

Lossy/delayed networks (Wi-Fi) does impact the results

- Optimize number of ROS2 nodes (currently +20 nodes/AMR)
- Cyclone DDS has better tolerance for impaired networks
- Limit ROS2 node discovery to the once required by the cloud

Reusable sQoS tool to benchmark more RMW middlewares, different ROS2 QoS settings or new versions of ROS2



Conclusions

Tested and benchmarked scalable ROS2/VPN framework for our RaaS

Fed4Fire testbeds have helped a lot in finding setup challenges, configuration issues, and gaining the knowledge of distributed ROS2 setup

Further validated ROS2 security features and gained more insight in ROS2 optimization

Changed from default ROS2 RMW to Cyclone DDS (direct link to developers)

RaaS-o-ROS2 needs further optimization to limit meta traffic between ROS2 nodes, and optimize the on robot topics/services with shared memory





Omnit @ IMEC's industrial IoT lab



Benefits of Fed4Fire and Next Steps

Accelerated development of the scalability of our RaaS platform

Financing was extremely helpful - gained knowledge in distributed setups, ROS2 optimization, multi-site support over Wireguard VPN, etc.

Experience has helped us identify next optimization steps

- Implement shared memory communication for on robot topics and services
- Configure Cyclone DDS to further enhance performance on impaired networks
- Use SROS2 not only for encryption but for authentication and permissions
- Work together with the ROS community to further improve the performance of all RMW middlewares

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Ready for the next major step in going to production: making the Omnit SAFE



Safety Field Protection





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