Workshop on Autonomous Systems Design (ASD2019)

Bringing the Next Generation Robot Operating System on Deeply Embedded Autonomous Platforms

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Bringing ROS 2 on Microcontrollers

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Bringing ROS 2 on Microcontrollers

What is the Robot Operating System? (ros.org)

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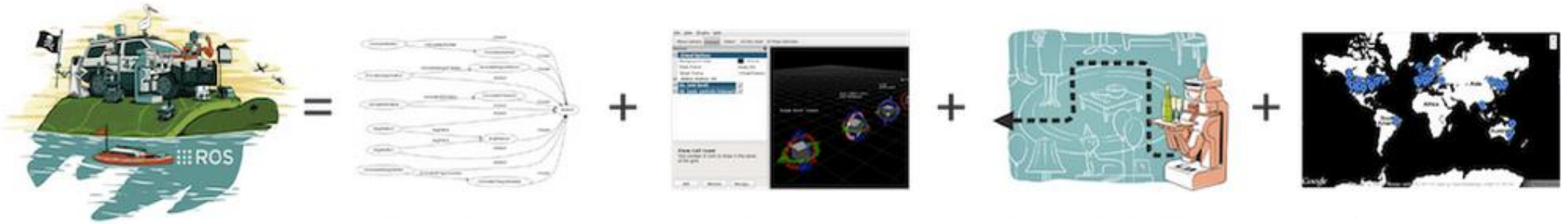
Bringing ROS 2 on Microcontrollers

The ROS Equation



Plumbing

- Process management
- Communication
- Device drivers
- Data models
- Language-independence

Tools

- Visualization
- Simulation
- Data recording
- Monitoring

Capabilities

- Control
- Perception
- Planning
- Manipulation

Ecosystem

- Shared development
- Robot models
- Documentation
- Exchange
- Market

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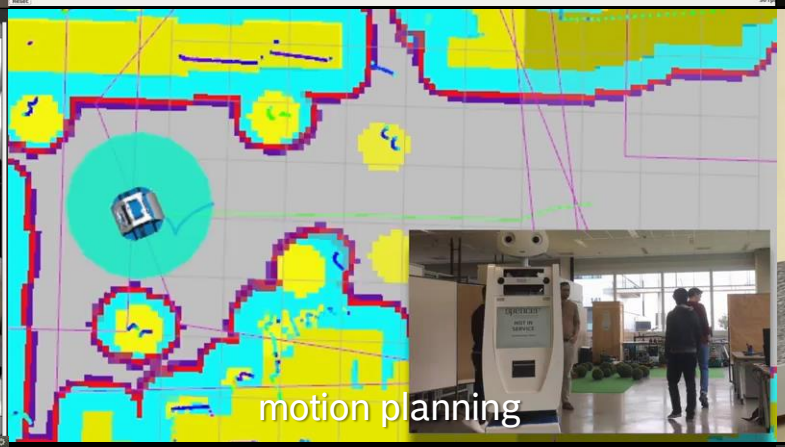
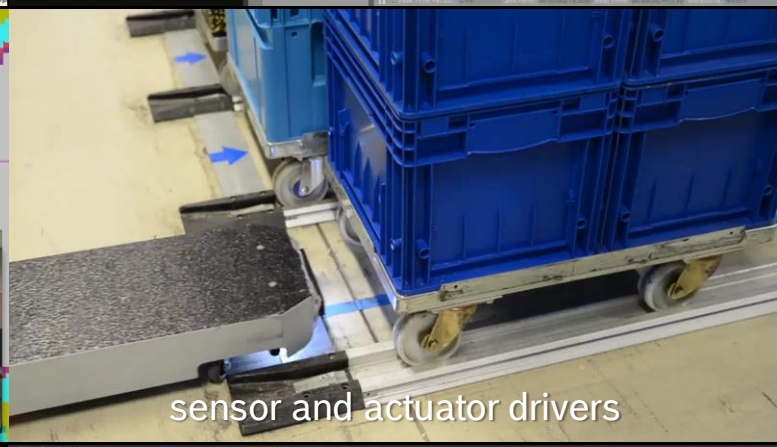
nav stack

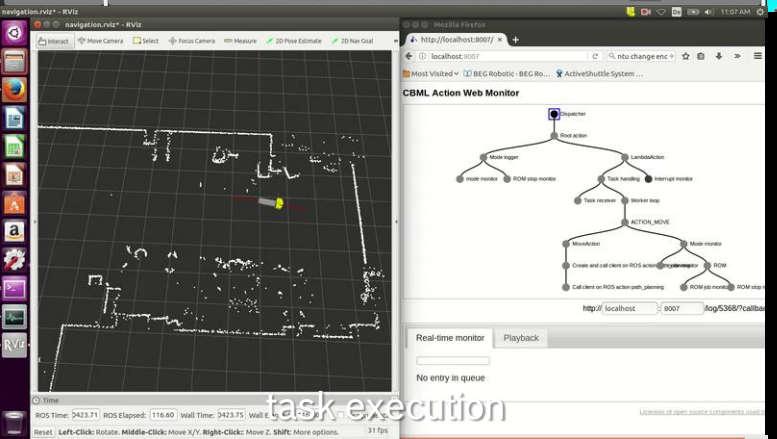

MoveIt

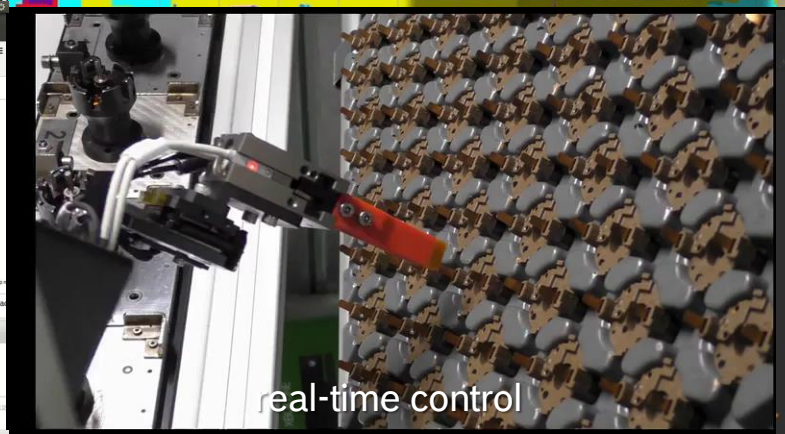

Gazebo simulator

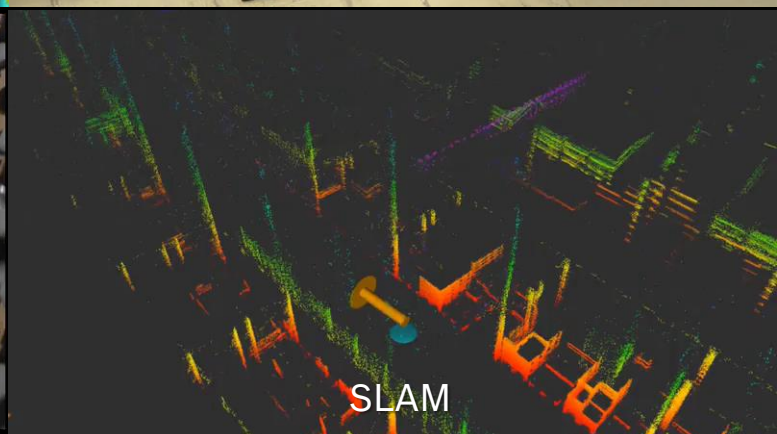

Gazebo simulator


motion planning


sensor and actuator drivers

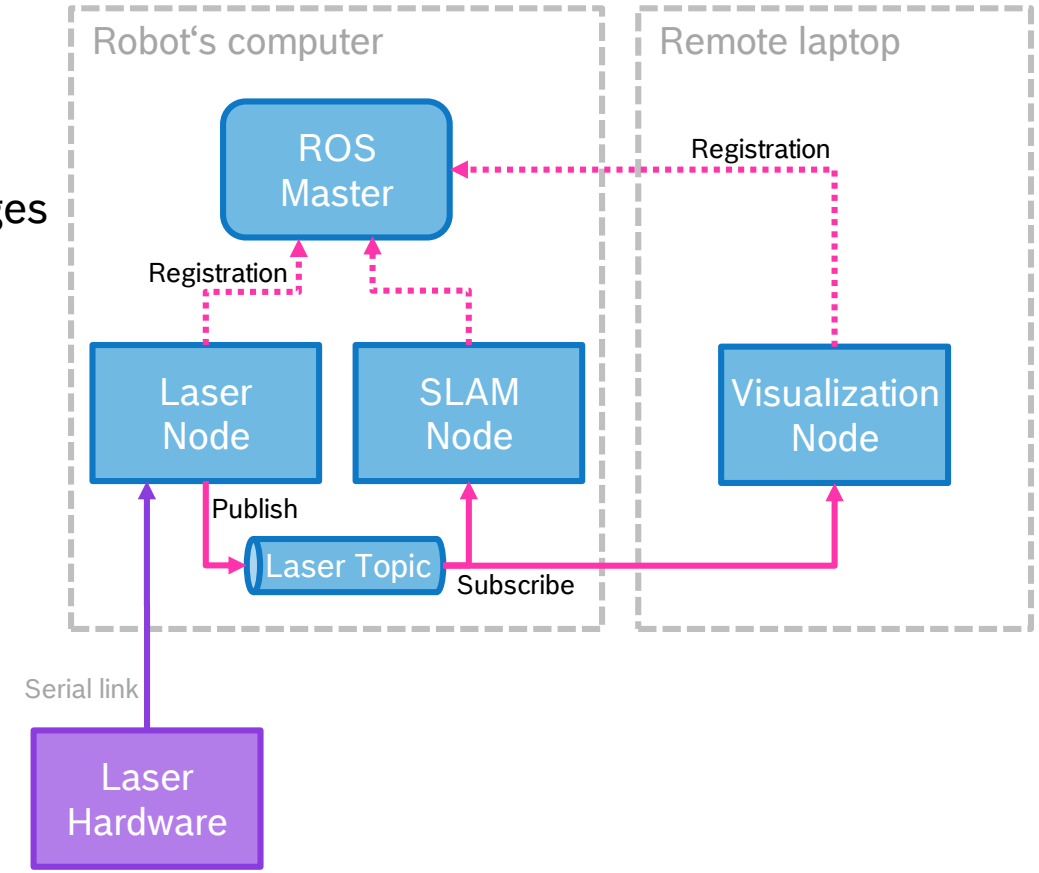

CBML Action Web Monitor
Real-time monitor
Playback
No entry in queue
task execution


real-time control


SLAM

Bringing ROS 2 on Microcontrollers
Architectural Principles

- Basic entity: *Nodes* (components) which exchange messages
- Can be distributed across machines
- Standard communication patterns
  - *Topics*: Publish-Subscribe (1 – n, uni-directional, async)
  - *Services*: Request-Response (n – 1, bi-directional, sync+async)
  - *Actions:* Advanced Request-Response (1-1, multi-state)
- Nodes comprised of *callables* (functions), which are *data-* or *time-triggered*
  - Implemented in C++, Python, ...
  - Run-to-completion
- Further core functionalities: Parameters, coordinate transformation, diagnostics, ...

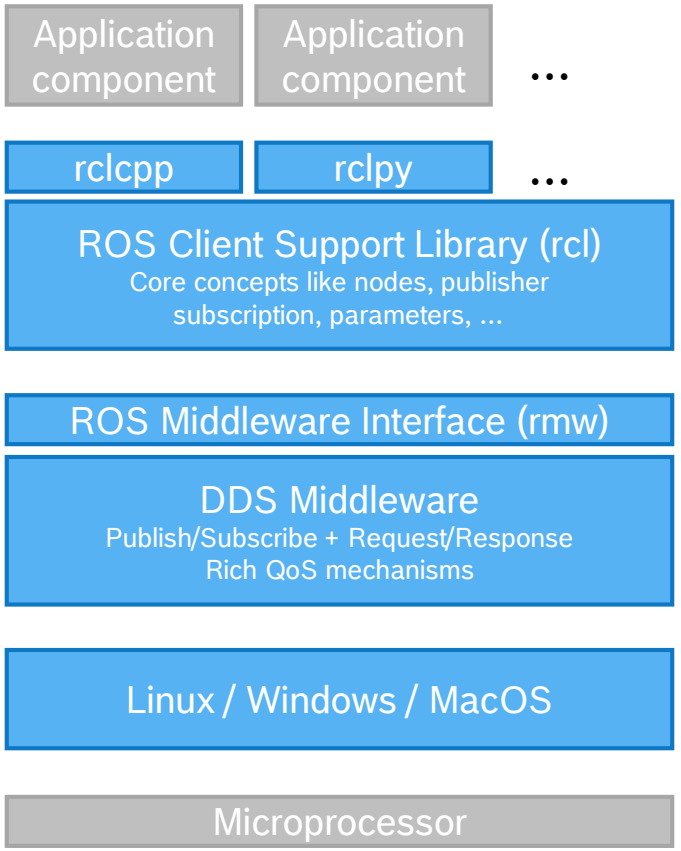


Bringing ROS 2 on Microcontrollers
ROS goes for series development

Key features of ROS 2

- Data Distribution Service (DDS) as middleware
- Run multiple nodes in one process
- Node lifecycle
- Deterministic launch
- ROS core functionality implemented in C
- Real-time-ready core algorithms
- Support of Windows and MacOS

- Backed by Technical Steering Committee with Intel, Amazon, Microsoft, Bosch, Arm, Apex.AI, Toyota Research, TARDEC, LG Electronics, eProsima, Acutronic Robotics, ...



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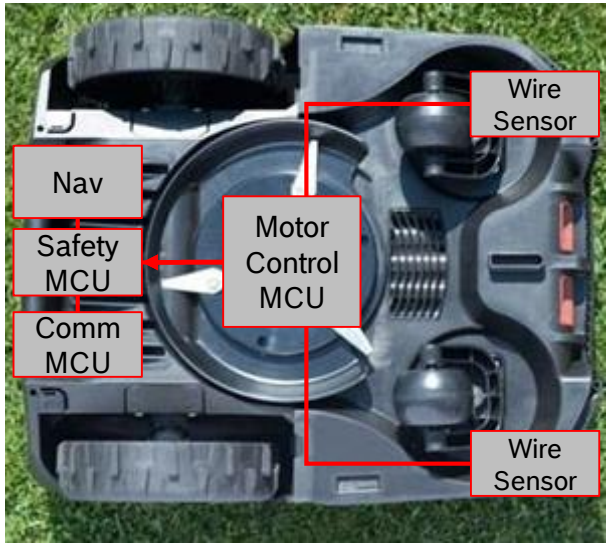
Bringing ROS 2 on Microcontrollers

ROS is great for development on microprocessors …

… but robots are networks of computing devices!

Bringing ROS 2 on Microcontrollers
Why microcontrollers?



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Hardware access

- GPIOs, PWM generators, ...
- Buses such as CAN, UART, SPI I²C

Hard, low-latency real-time

- Context switching in less than 100 cycles

Power saving

- Linux single-board computer requires 10 to 100x more power than an MCU

Safety

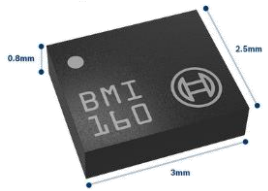
- Number of safety-certified RTOS available

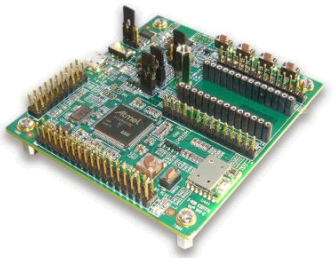
Bringing ROS 2 on Microcontrollers

EU project OFERA (Open Framework for Embedded Robot Applications)

Our mission: Bridge the gap between MCUs and larger processors by

μROS





- Seamless integration of MCUs with ROS 2
- Ease portability of ROS 2 code to MCUs
- Ensure long-term maintenance of micro-ROS stack

The OFERA project is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 780785

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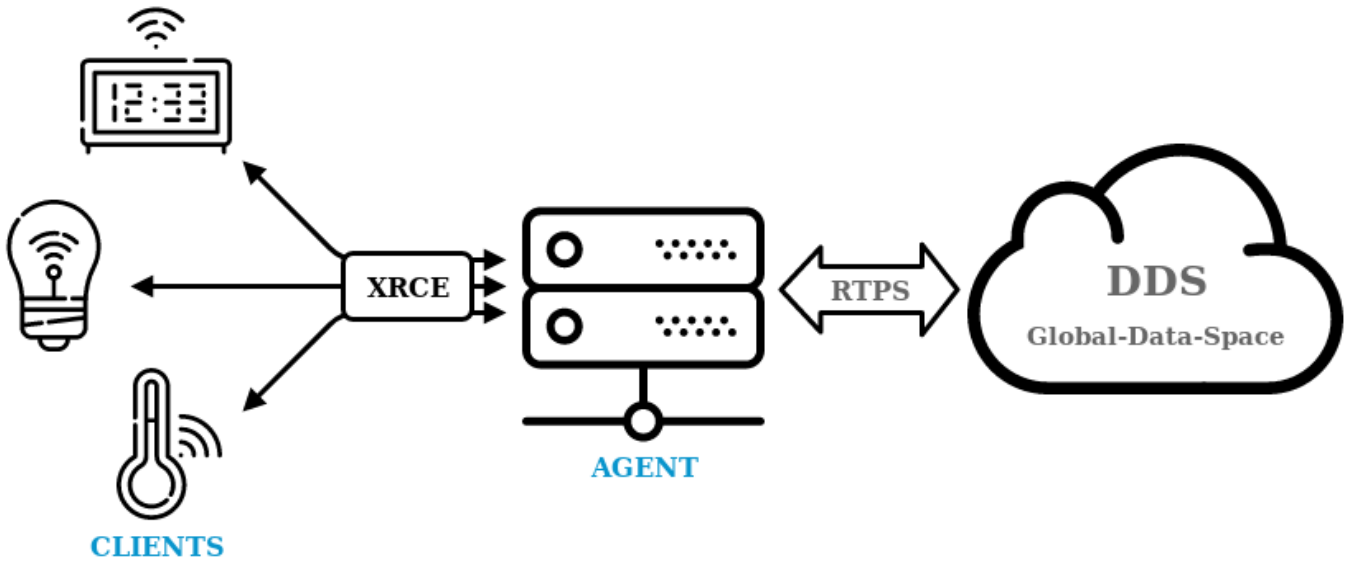
Bringing ROS 2 on Microcontrollers
New DDS-XRCE Standard



Open-source at github.com/eProsima/Micro-XRCE-DDS

- **D**ata **D**istribution **S**ervice
- OMG standard since 2004
- DDS-XRCE for
  e**X**tremely
  Resource
  Constrained
  Environments
  … brings DDS on MCUs
- DDS-XRCE standard is advanced by OFERA partner eProsima

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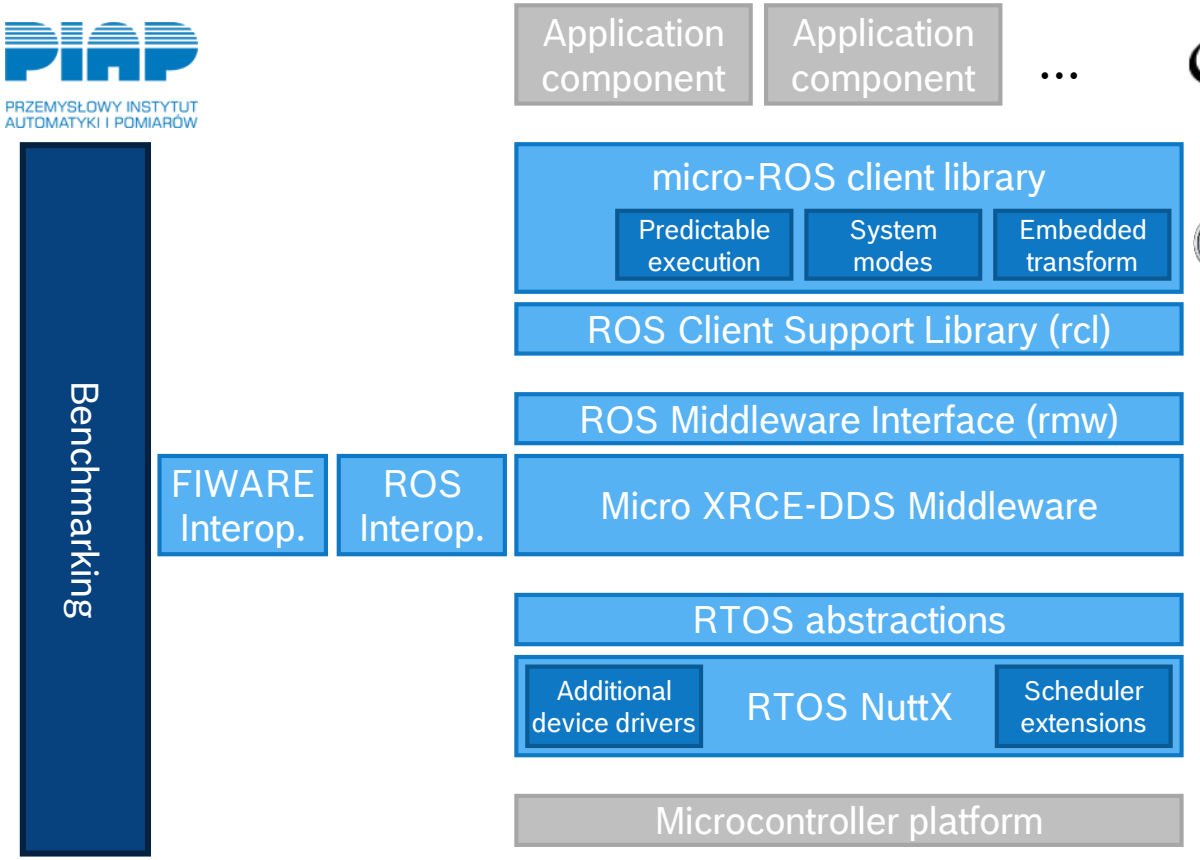
Bringing ROS 2 on Microcontrollers
Architecture

Two types of APIs:

1. Plain C API based on rcl for embedded developers
2. C++ API implemented against rclcpp interfaces for typical ROS developer



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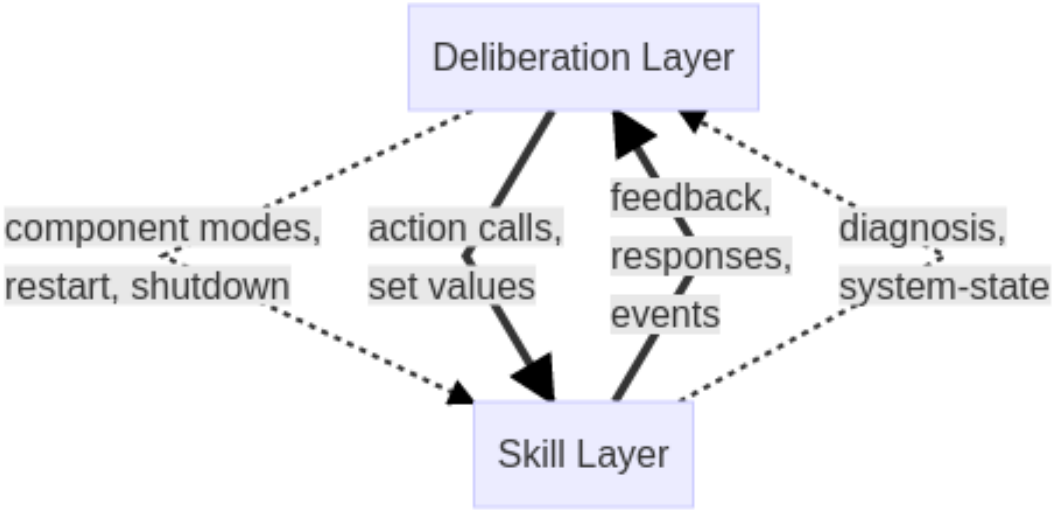
Bringing ROS 2 on Microcontrollers
micro-ROS Client Library Features: System Modes

- **Task Handling**: Orchestration of the actual task, the straight-forward, error-free flow
- **Contingency Handling**: Handling of task-specific contingencies, e.g., expectable retries and failure attempts, obstacles, low battery
- **System Error Handling**: Handling of exceptions, e.g., sensor/actuator failures



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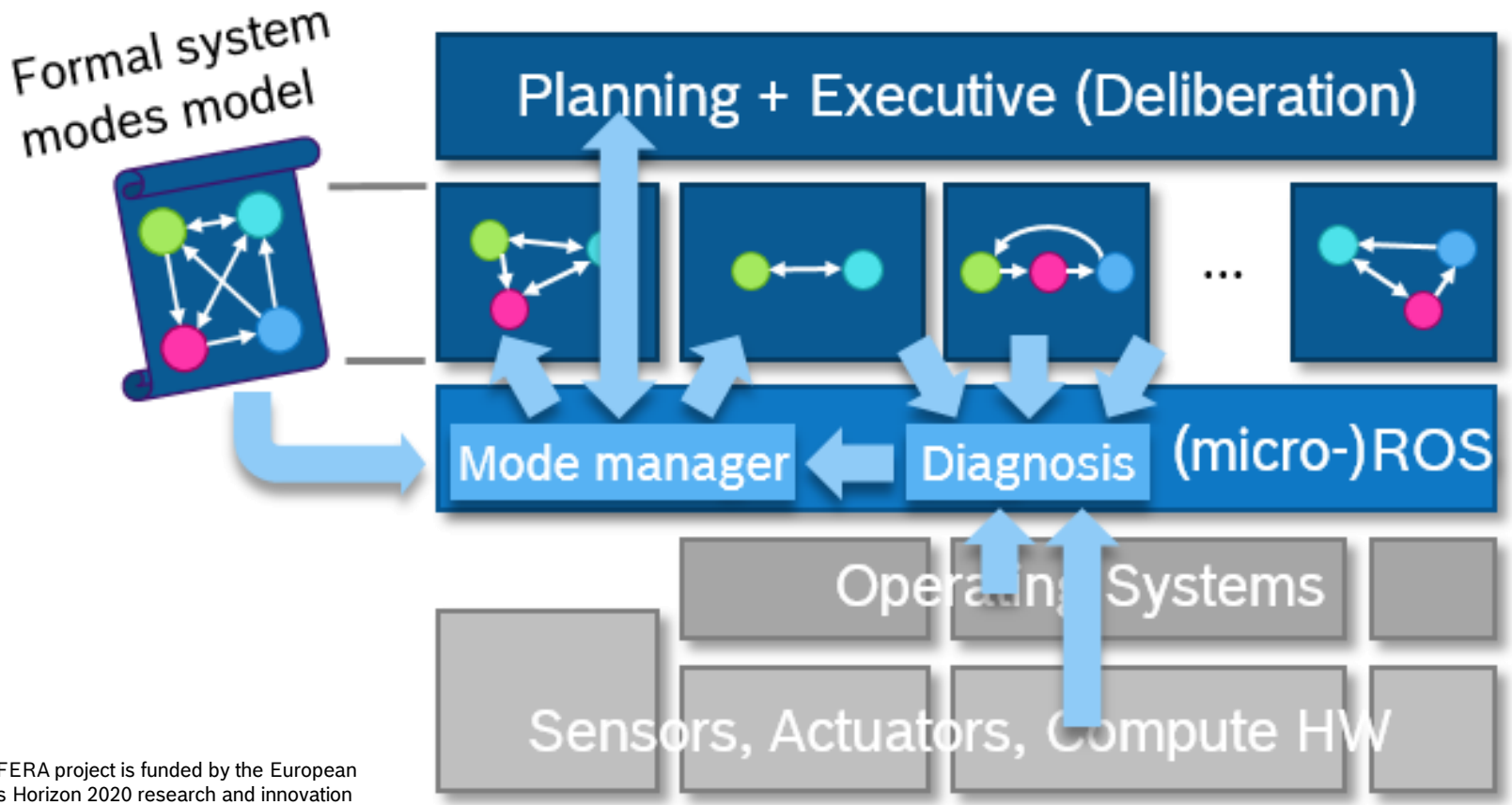

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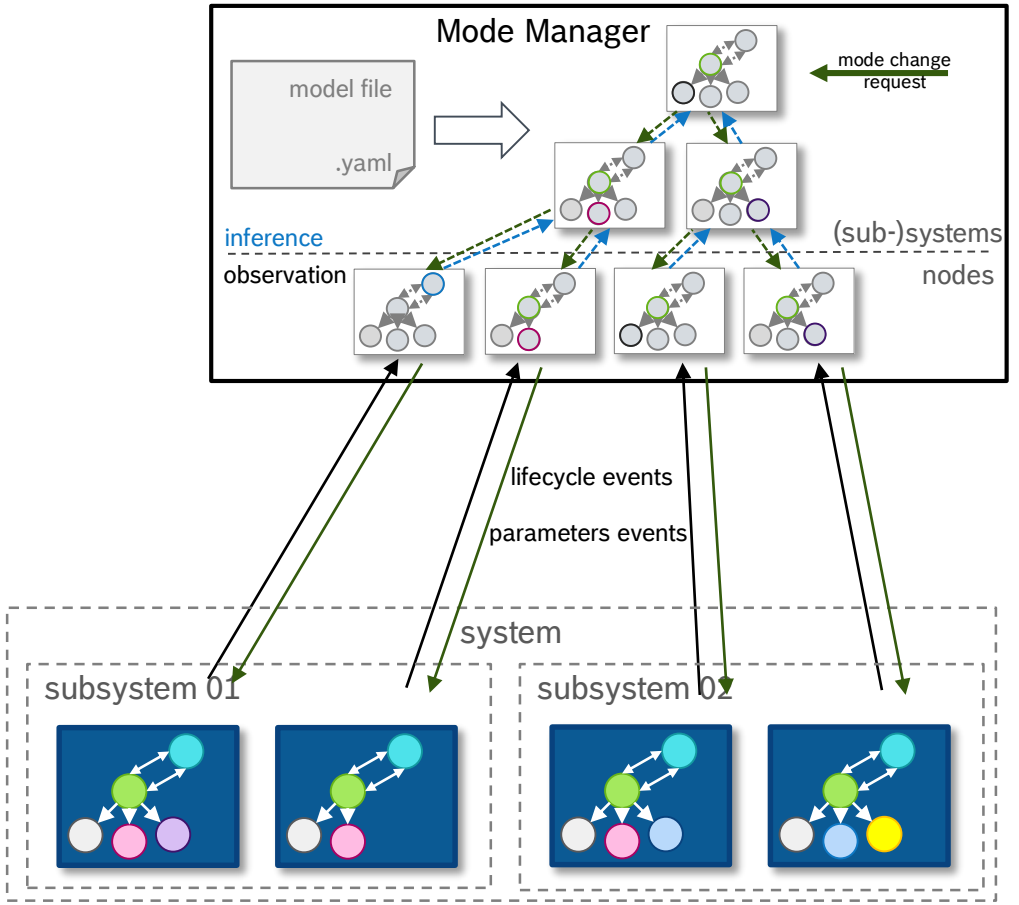
Bringing ROS 2 on Microcontrollers
micro-ROS Client Library Features: System Modes

- Introduces **(sub-)systems** hierarchy to ROS 2
- Abstraction for hierarchical configuration, called **system modes**
- **Mode manager** manages consistent, system-wide configuration
- See **micro-ros.github.io/system_modes/**



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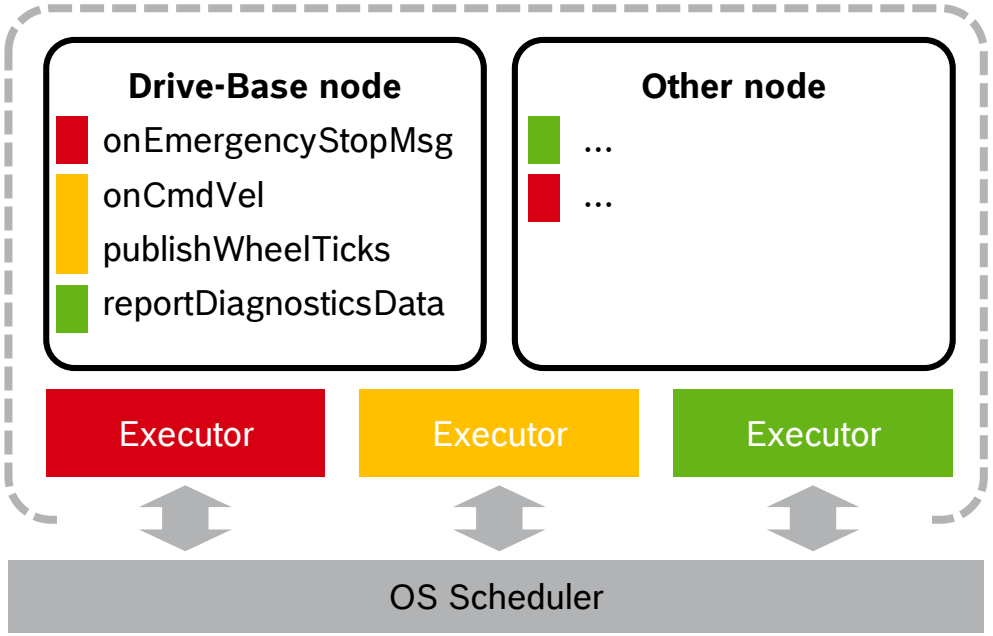
Bringing ROS 2 on Microcontrollers
micro-ROS Client Library Features: Predictable Execution

- First approach enables **multiple executors** per operating system process
- Executors can be configured individually using standard scheduling mechanisms
- Open-sourced prototype for ROS 2
- See **micro-ros.github.io/real-time_executor/**



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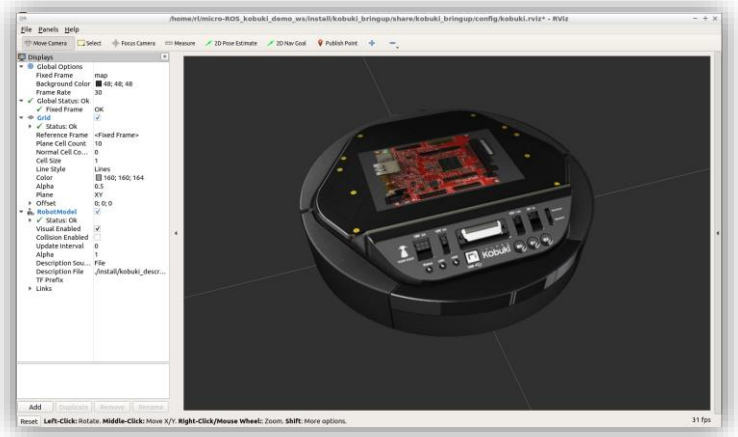
Bringing ROS 2 on Microcontrollers

Community Use-Case: Kobuki with STM32 F4 Cortex-M4



ROS 2 (Crystal) running
- Visualization
- Keyboard control
- odometry to TF
- DDS <-> DDS-XRCE agent

DDS-XRCE over UDP

micro-ROS running
- thin_kobuki_driver
- DDS-XRCE client

at less than 100 KB RAM

Preliminary version at github.com/micro-ROS/micro-ROS_kobuki_demo

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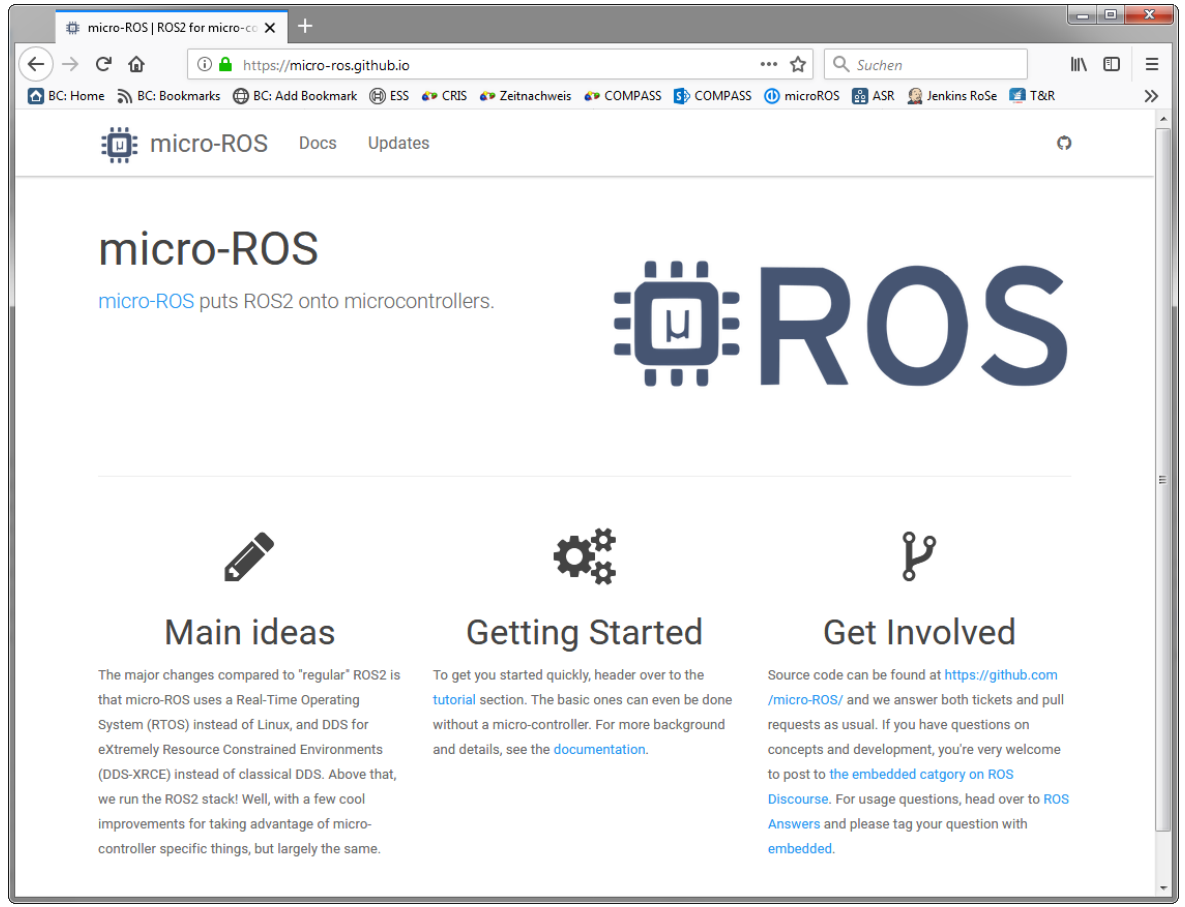
Further information

https://micro-ros.github.io/

+ Join discussion in ROS 2 Embedded SIG at discourse.ros.org/c/embedded



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