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ROSCon 2022: Native Rust

Contents

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In business for 23 years
~120 employees
Turnover ~ 9 M€
Owned by personnel

Digitalization Engineering

Machines and Automation
Healthcare and Social Services
Public Sector IT

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Why Rust is important for robot programming

Rust is so far the best candidate for replacing C and C++ in systems programming.

Produces low-overhead bare-metal code like C++
– with safety guarantees of a high-level language:

- Memory safety
- Data race safety*
- Reasonably easy to learn for C++ programmers
- Algebraic type system

No historical baggage of C/C++:

- Undefined or implementation-defined behaviour
- Large bag of pitfalls to learn

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* Yes, really! The compiler can statically detect data races!
(But deadlocks are still on the programmer's responsibility.)

How does Rust achieve that?

- Ownership-based memory handling
  - Handles a mix of stack and heap allocations
    - Stack allocation beats even the fastest malloc library
  - Statically checked lifetimes → zero overhead
  - Also checks safe memory sharing between threads

- unsafe constructs
  - Clearly separates dangerous constructs, e.g. raw pointer handling, from safe code.
  - unsafe is needed for very low-level data structure implementations and FFI, but that is a very small fraction of code lines.

- Compiler is built on LLVM
  - Very advanced back-ends for x86(-64), ARM, and others

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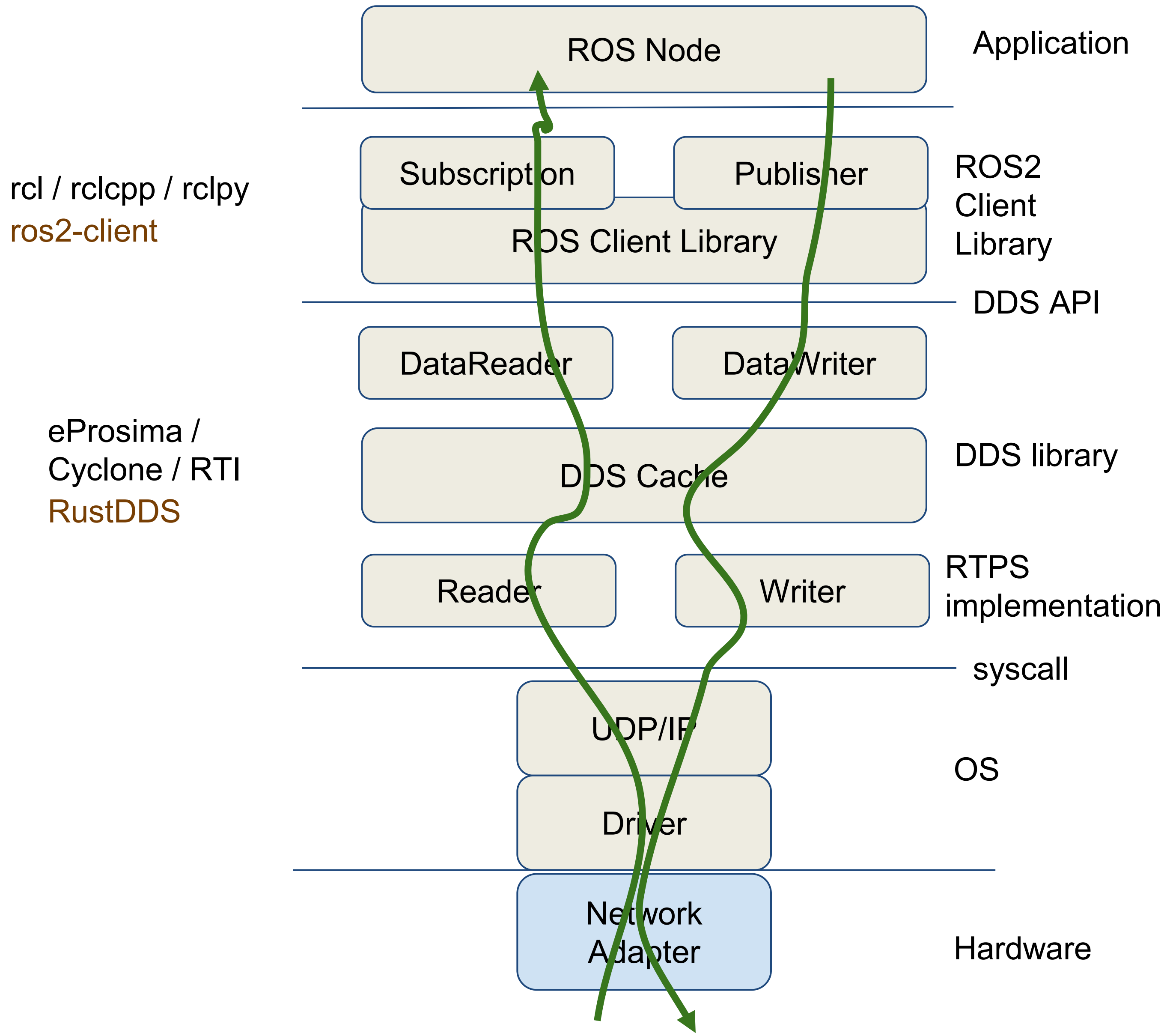
Programming ROS2 with Rust

ROS2 client in Rust: Alternatives

Name	Author	URL	Notes
ros2-rust	Multiple contributors	https://github.com/ros2-rust/ros2_rust	Official Rust binding to rcl
ros2-client / RustDDS	Atostek Oy / Juhana Helovuo and others	https://github.com/jhelovuo/ros2-client	Native Rust implementation of ROS2 client library - and DDS!
r2r	Martin Dahl and others	https://github.com/sequenceplanner/r2r	Binding to rcl. Rust API uses async functions.
rclrust	Yuma Hiramatsu	https://github.com/rclrust/rclrust	Uses Rust macros(!) to translate IDL to Rust types.
rus2	Marshal SHI	https://github.com/marshalshi/rus2	Inactive since Sep 2020
rosrust	Adnan Ademovic and others	https://github.com/adnanademovic	ROS 1 Inactive since Aug 2020

RustDDS

- Native Rust implementation of DDS API and RTPS network protocol from scratch
- Apache 2.0 -licensed open source: https://github.com/jhelovuo/RustDDS
- Features
  - Discovery (peer autodetection)
  - Non-blocking I/O
  - “Zero-copy” receive path
    - Single-copy transmit path
  - Serialize/deserialize directly to Rust objects
  - Reliable and Best Effort QoS
  - History QoS
  - Fragmentation (large objects)



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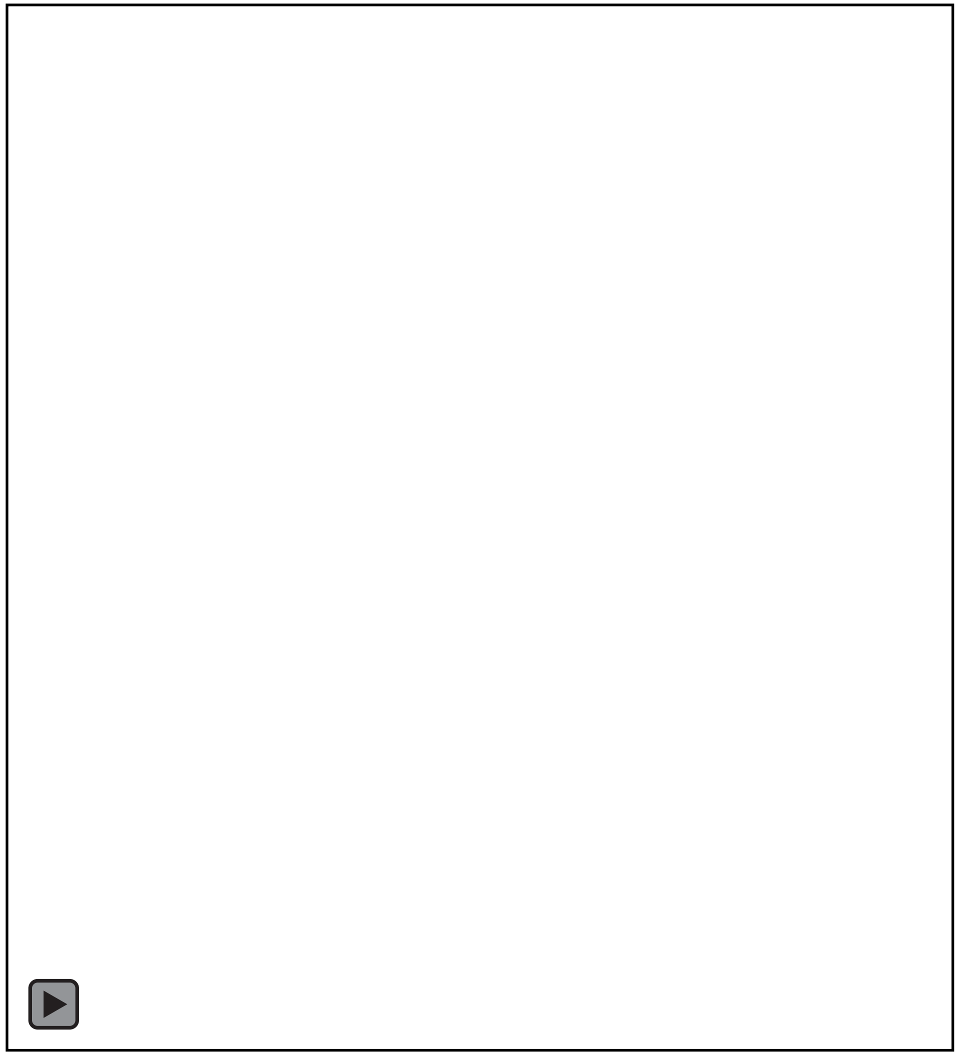
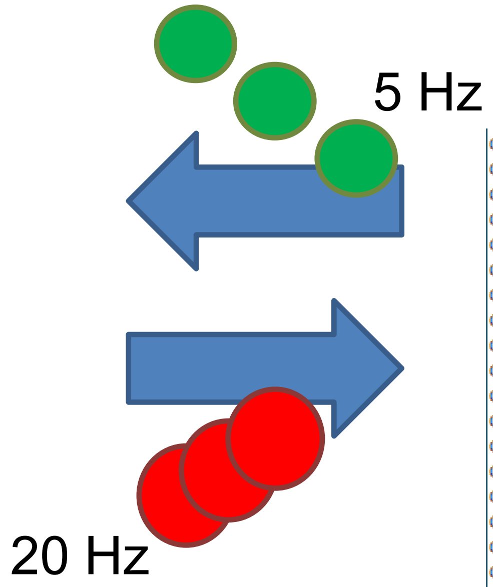
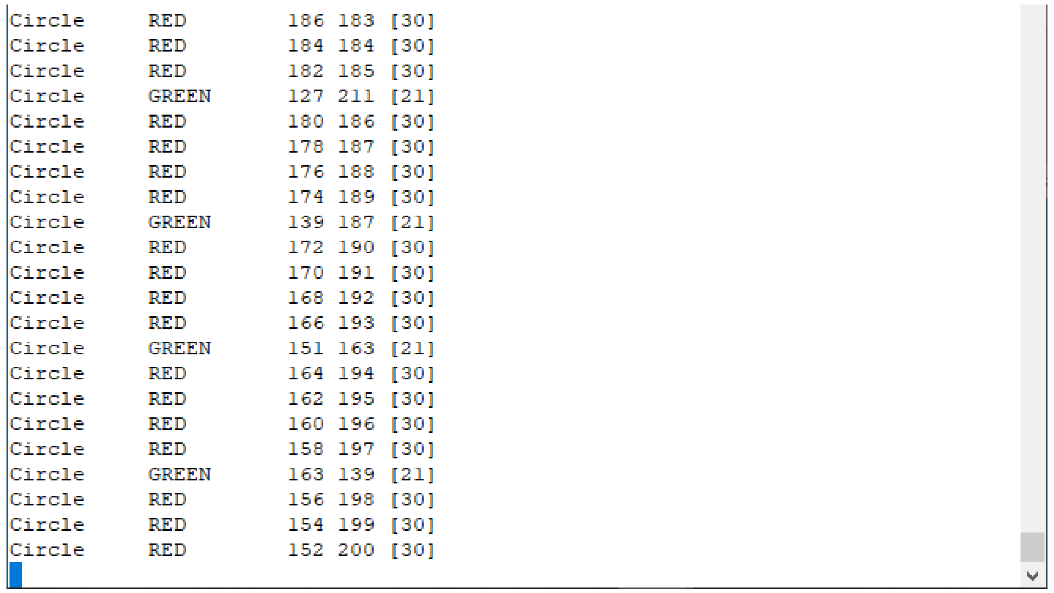
RustDDS



```
$ cargo run --example=shapes_demo
-- -P -t Circle -r -c GREEN -S
```





```
Circle     RED        186 183 [30]
Circle     RED        184 184 [30]
Circle     RED        182 185 [30]
Circle     GREEN      127 211 [21]
Circle     RED        180 186 [30]
Circle     RED        178 187 [30]
Circle     RED        176 188 [30]
Circle     RED        174 189 [30]
Circle     GREEN      139 187 [21]
Circle     RED        172 190 [30]
Circle     RED        170 191 [30]
Circle     RED        168 192 [30]
Circle     RED        166 193 [30]
Circle     GREEN      151 163 [21]
Circle     RED        164 194 [30]
Circle     RED        162 195 [30]
Circle     RED        160 196 [30]
Circle     RED        158 197 [30]
Circle     GREEN      163 139 [21]
Circle     RED        156 198 [30]
Circle     RED        154 199 [30]
Circle     RED        152 200 [30]
```

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Code: Using RustDDS

```
#[derive(Serialize, Deserialize, Clone)]
struct Shape {
  color: String,
  x: i32,
  y: i32,
  shapesize: i32,
}
impl Keyed for Shape {
  type K = String;
  fn key(&self) -> String {
    self.color.clone()
  }
}

…

let domain_participant = DomainParticipant::new(domain_id)
  .unwrap_or_else(|e|
    panic!("DomainParticipant construction failed: {:?}", e));
```

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Code: Using RustDDS

```
poll.poll(&mut events, Some(loop_delay)).unwrap();
for event in &events {
  match event.token() {
   // ...
   READER_READY => {
     // ...
     match reader.take_next_sample() {
         Ok(Some(s)) =>
           match s.into_value() {
             Ok(sample) => println!( "{:10.10} {:10.10} {:3.3} {:3.3} [{}]",
                   topic.name(), sample.color, sample.x, sample.y, sample.shapesize, ),
             Err(key) => println!("Disposed key {:?}", key),
           },
         Ok(None) => break, // no more data
         Err(e) => println!("DataReader error {:?}", e),
     }
   }
```

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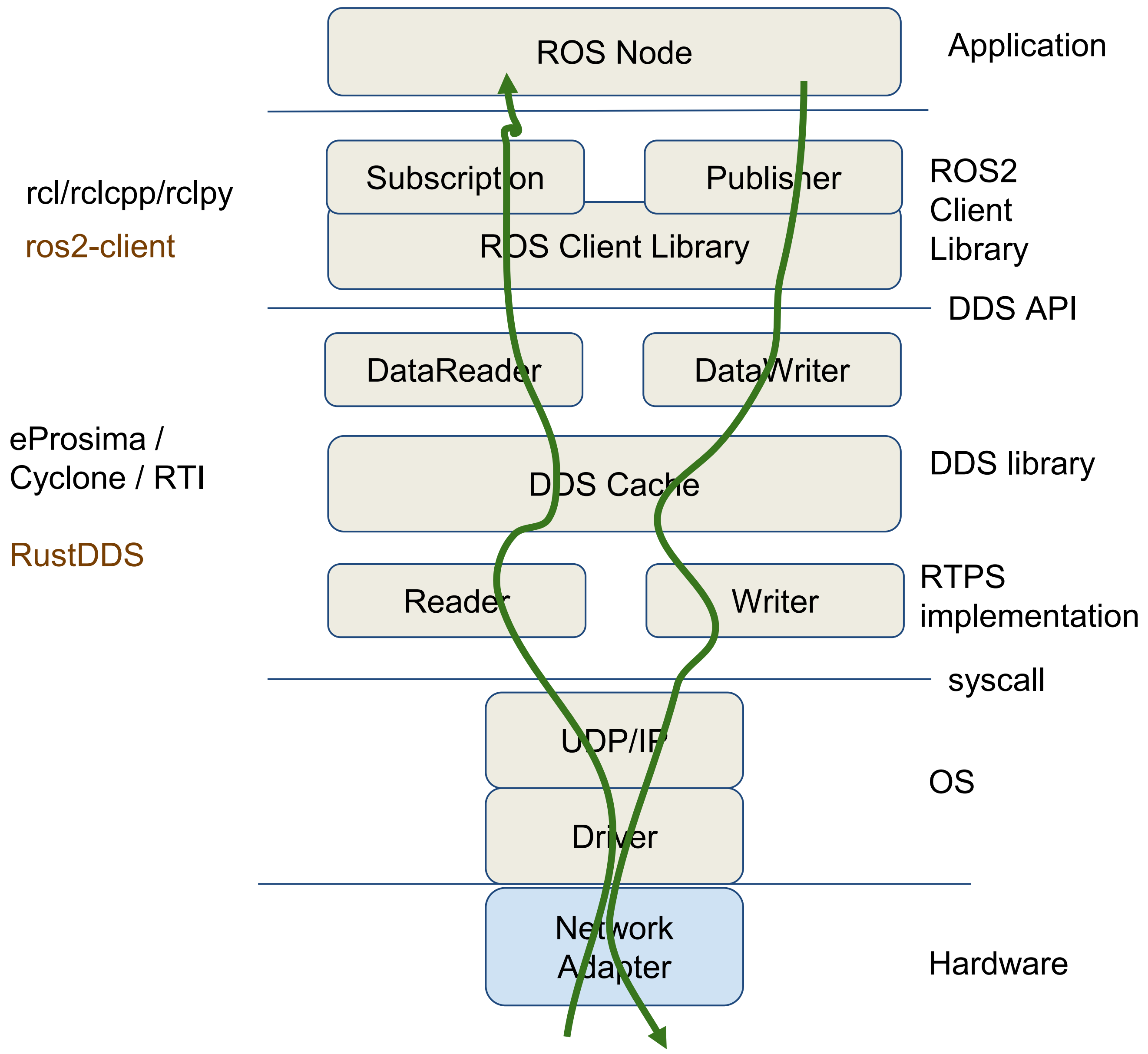
Code has been edited for presentability. Please see sources at GitHub for full version.

ros2-client

- ros2 - client is a Rust crate that implements something similar to rcl and (parts of) rclcpp/rclpy.
  - Topics
  - Services
- Runs on top of RustDDS.
- Does not yet have an event loop. Nodes must use .poll() from the Metal I/O library to implement event loop.



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Code: Using ros2-client

```
let mut node = create_node();
let topic_qos = create_qos();
let chatter_topic = node
  .create_topic( "/chatter",
    String::from("std_msgs::msg::dds_::String_"),
    &topic_qos, )
  .unwrap();
let mut chatter_subscription = node
   .create_subscription::<String>(&chatter_topic, None)
   .unwrap();

// ... initialize polling here ...
```

```
loop {
  poll.poll(&mut events, None)
    .unwrap();
  for event in events.iter() {
    match event.token() {
      Token(1) => match chatter_subscription.take() {
        Ok(Some((message, _messafe_info))) => {
          let l = message.len();
          println!("message len={} : {:?}", l, &message[..min(l,50)]);
        }
        Ok(None) => println!("No message?!"),
        Err(e) => {
          println!(">>> error with response handling, e: {:?}", e)
        }
      },
      _ => println!(">>> Unknown poll token {:?}", event.token()),
    } // match
  } // for
} // loop
```

Code has been edited for presentability. Please see sources at GitHub for full version.

The Flexbot Framework

- Robot programming framework developed at Atostek since 2019.
- Not (yet) open source
- Main idea is to construct software from nodes and communication channels just like in ROS.
- We implemented ROS2-compatibility in 2020-2021 → Flexbot can be now seen as an extension to ROS2.
  - Supports programming nodes in Rust.
  - Whole software is described by a machine-readable data flow specification.
  - Boilerplate code is generated from the specification
  - Closely coupled nodes can simplify inter-node communication
  - → Enables fine-grained data flow programming with tens or hundreds of nodes.
  - → Simple individual nodes → Improved reusability

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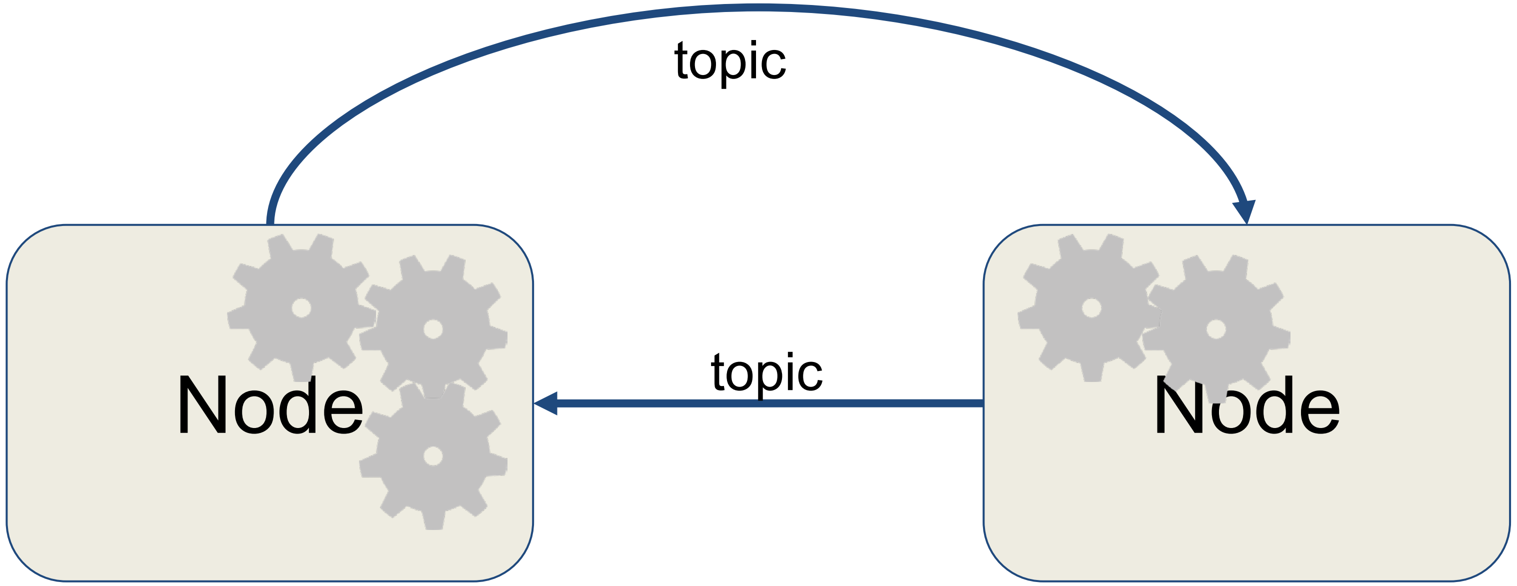
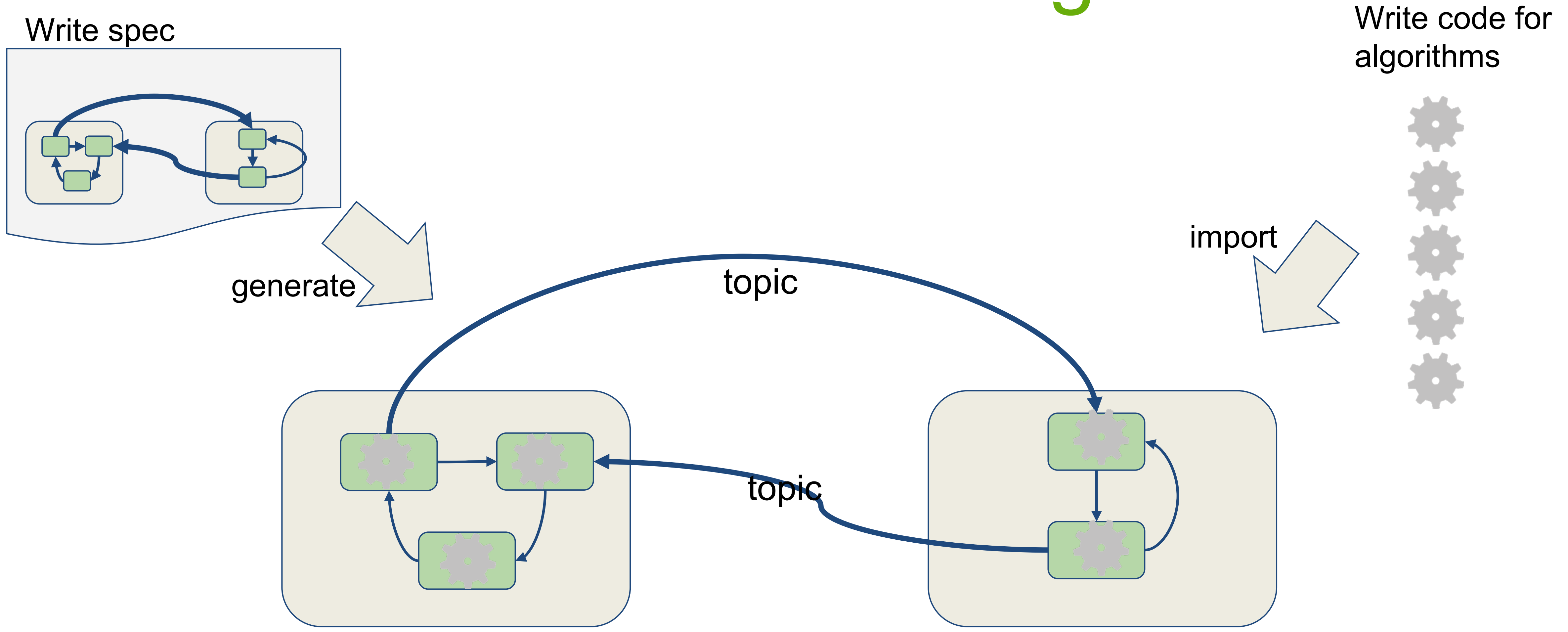
ROS2: high-level view



ROS2 and Flexbot together



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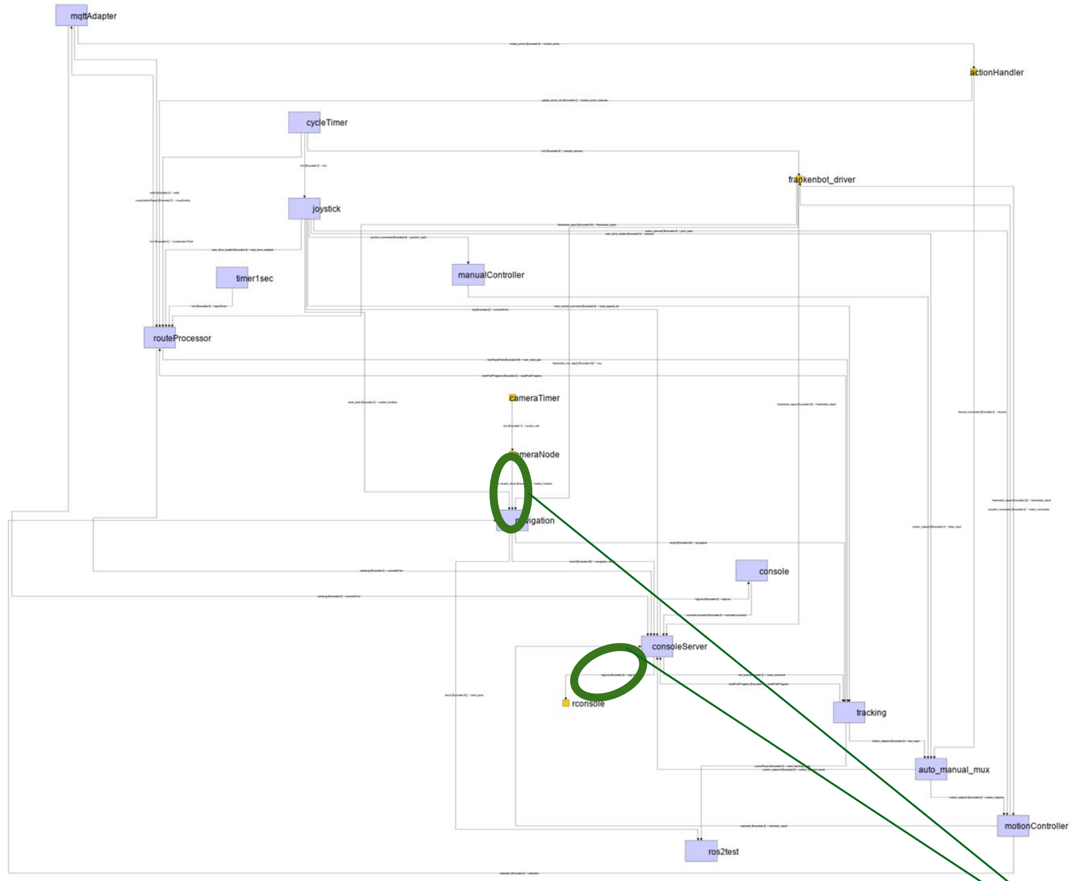
Flexbot Example: Pulu robot path tracking

- Vehicle mechanics & electrics: Pulu Robotics, prototype
- Main controller: Raspberry Pi 4
- Camera navigation: 2 x (RPi3 + Raspberry Camera module)
- Software: ”atosbot” application using Flexbot framework

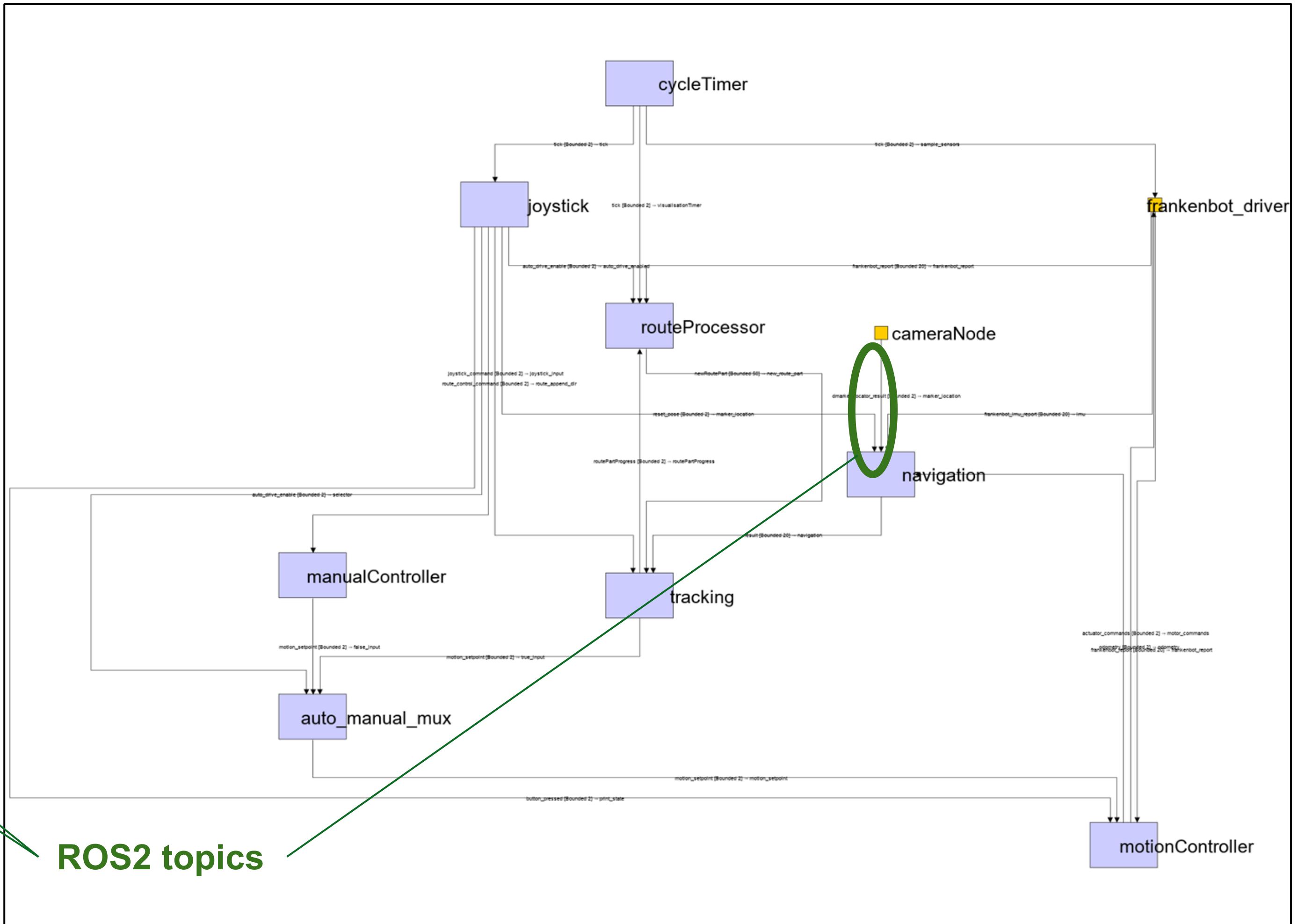
- Rviz2 - ROS2 Foxy, pre-built binary on Ubuntu Linux

Flexbot Example: Pulu robot path tracking

Full Data flow Graph



Simplified


cycleTimer
tick [Bounded 2] → tick
tick [Bounded 2] → sample_sensors
joystick
tick [Bounded 2] → visualisationTimer
frankenbot_driver
auto_drive_enable [Bounded 2] → auto_drive_enabled
frankenbot_report [Bounded 20] → frankenbot_report
routeProcessor
cameraNode
joystick_command [Bounded 2] → joystick_input
route_control_command [Bounded 2] → route_append_dir
newRoutePart [Bounded 50] → new_route_part
dmarker_locator_result [Bounded 2] → marker_location
reset_pose [Bounded 2] → marker_location
frankenbot_imu_report [Bounded 20] → imu
routePartProgress [Bounded 2] → routePartProgress
navigation
auto_drive_enable [Bounded 2] → selector
result [Bounded 20] → navigation
manualController
tracking
actuator_commands [Bounded 2] → motor_commands
odometry [Bounded 2] → odometry
frankenbot_report [Bounded 20] → frankenbot_report
motion_setpoint [Bounded 2] → false_input
motion_setpoint [Bounded 2] → true_input
auto_manual_mux
motion_setpoint [Bounded 2] → motion_setpoint
button_pressed [Bounded 2] → print_state
motionController

ROS2 topics

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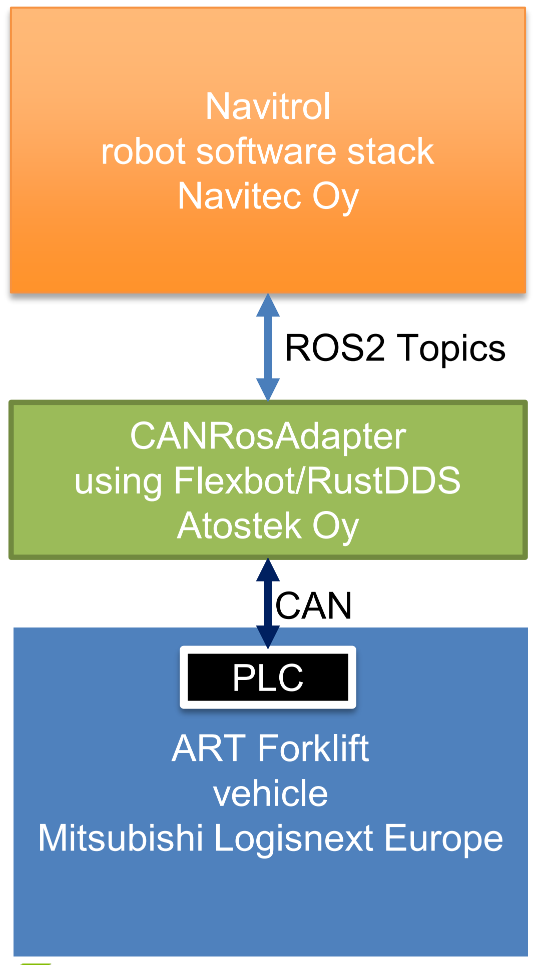
Automated Forklift

Mitsubishi Logisnext Europe
Demo Center, Järvenpää, Finland
Manual teleoperation test,
using software from multiple vendors.



Summary

- Rust is important for robots
  - No-overhead real-time systems programming capability like C/C++
  - Very good memory safety, no garbage collection required
  - Type system more straightforward than C++ classes, but still powerful
- RustDDS
  - Open-source native Rust DDS/RTPS implementation from Atostek
- ros2-client
  - ROS2 topics and services on top of RustDDS
  - Enables ROS2 nodes in native Rust
- Flexbot
  - Framework to produce ROS2-compatible dataflow software
  - Code generation from machine readable specification
    - Local-only data channels use very lightweight communication
    - Enables scaling to large number of nodes.