The Future of the Robot Operating System

ROS 2.0

Open Source Team

Yoonseok Pyo

Contents

Contents

ROSCon2015

Hamburg, Germany October 3-4, 2015

ROSCon2015

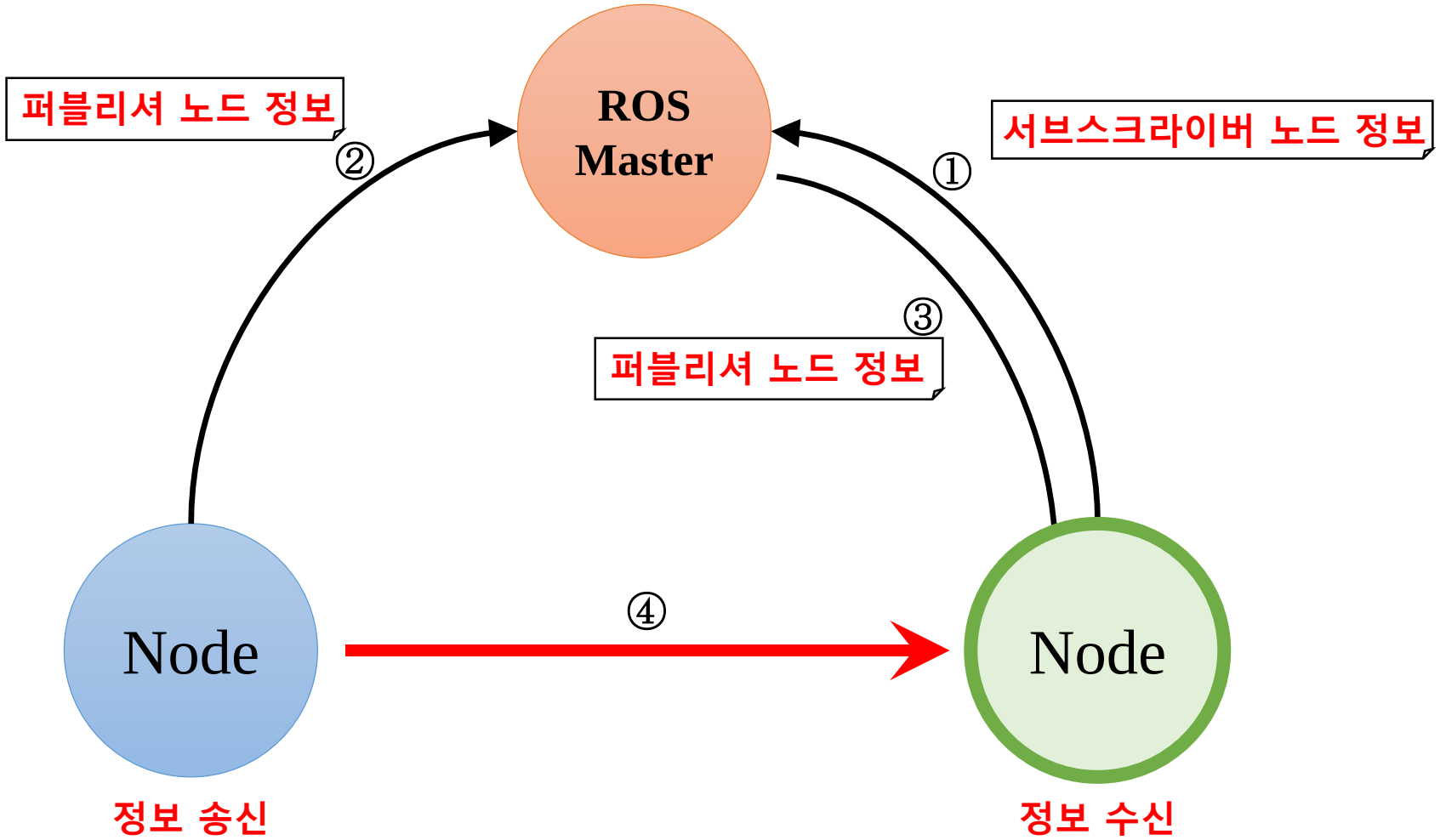
Hamburg, Germany October 3-4, 2015

Why ROS 2?

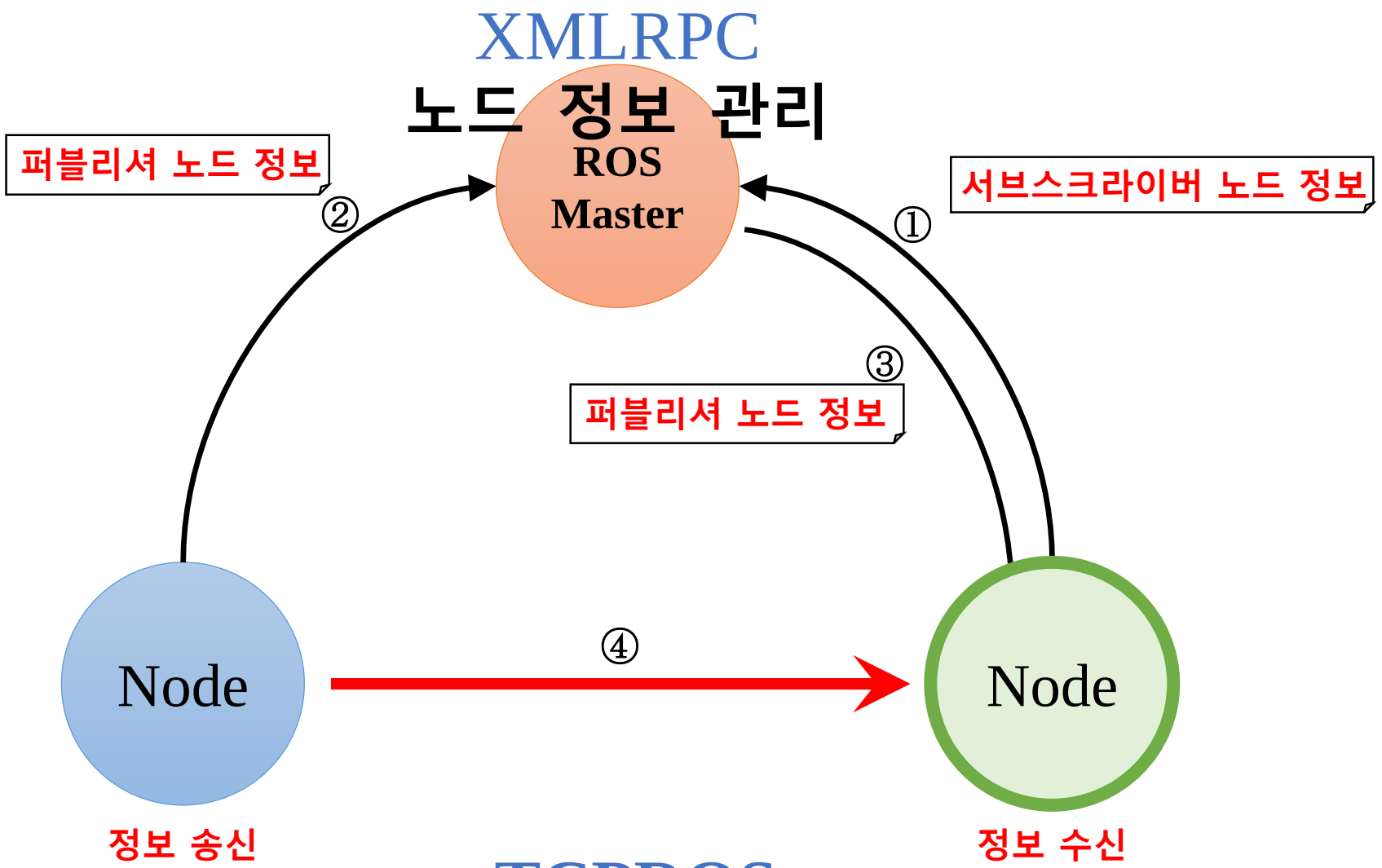
- Multiple robots
- Small embedded platforms
- Real-time systems
- Non-ideal networks
- Production environments
- Prescribed patterns for building and structuring systems
- New technologies: Zeroconf, Protocol Buffers, ZeroMQ, Redis, WebSockets, DDS (Data Distribution Service)
- API changes
- Risk associated with changing the current ROS system

Contents

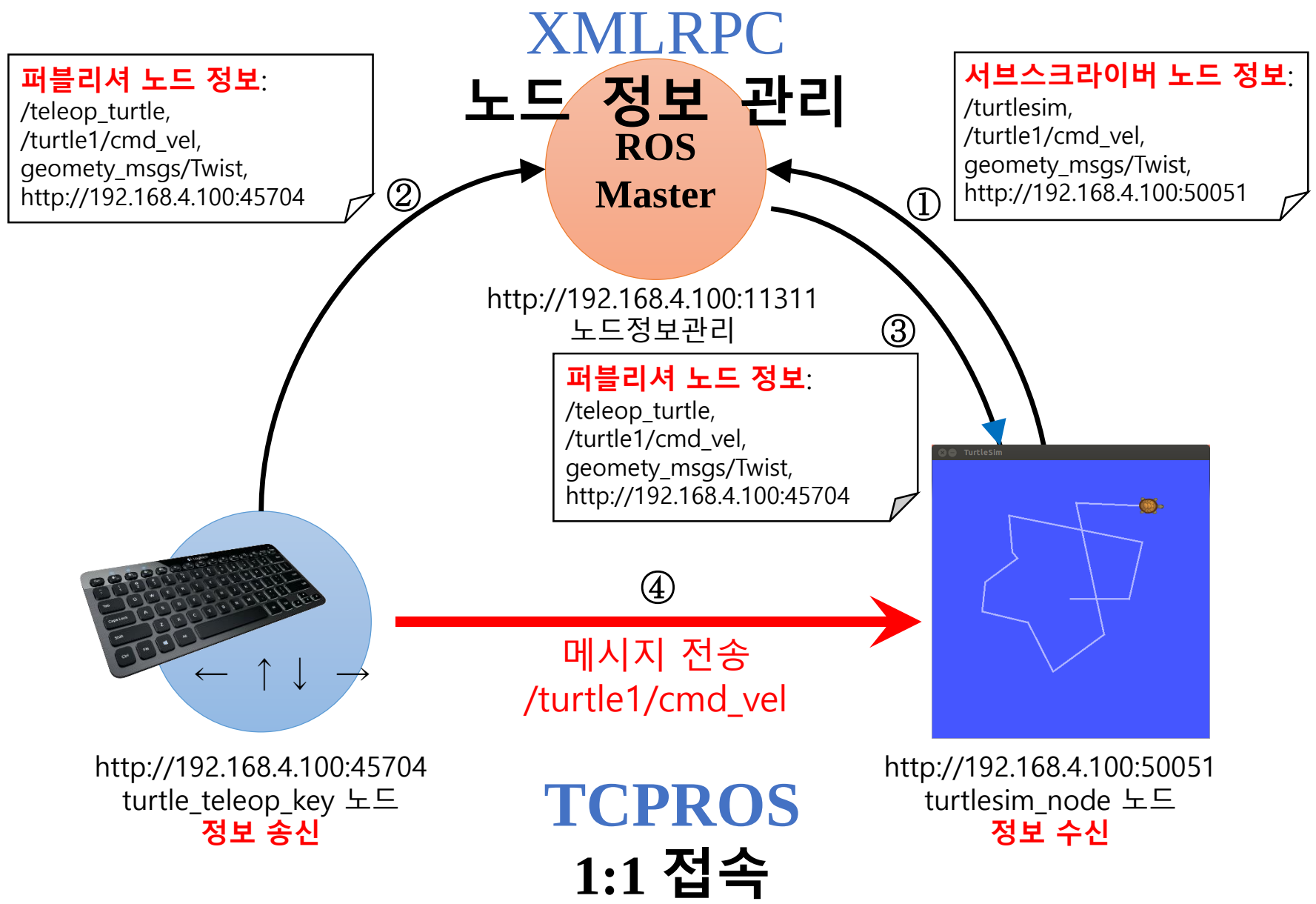
ROS 1.x (XMLRPC + TCPROS)



ROS 1.x (XMLRPC + TCPROS)

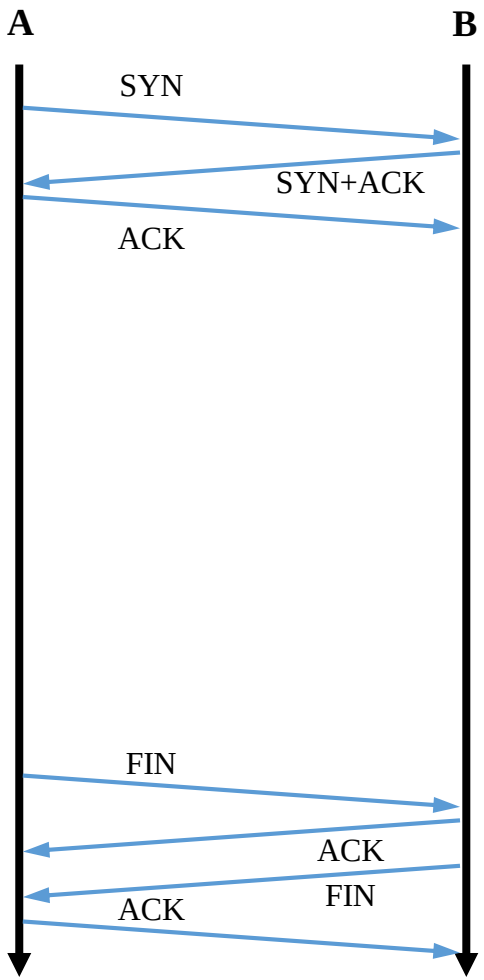


ROS 1.x (XMLRPC + TCPROS)



Transport: TCP vs UDP

TCP



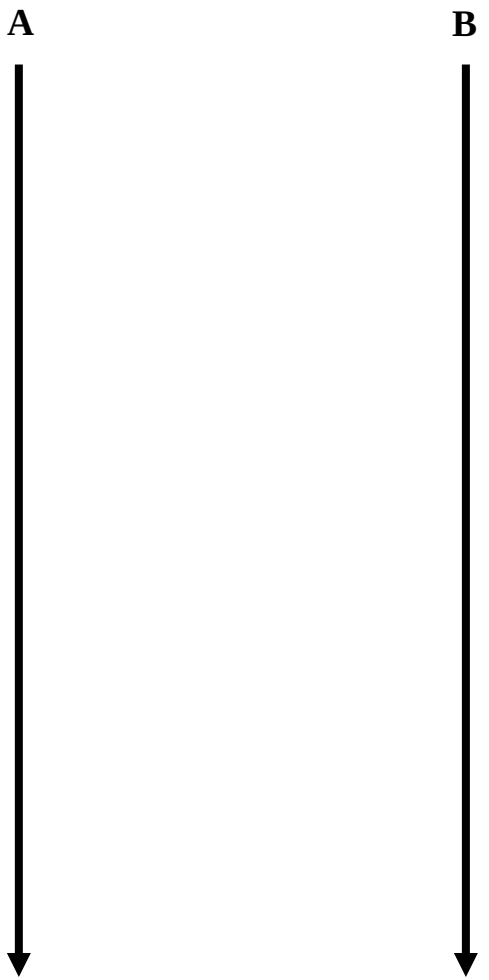
Connection establishment

Connection termination

Connection-oriented

Unicast

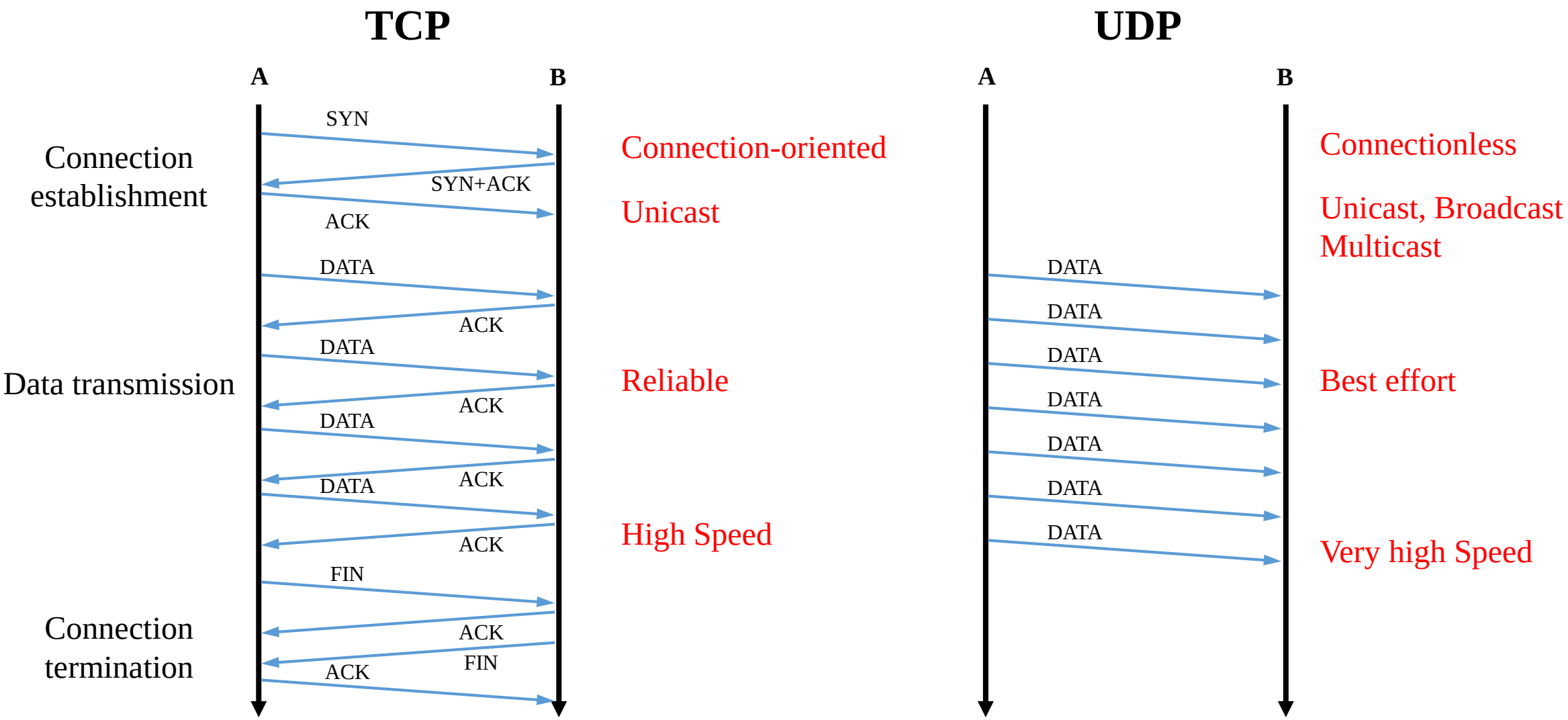
UDP



Connectionless

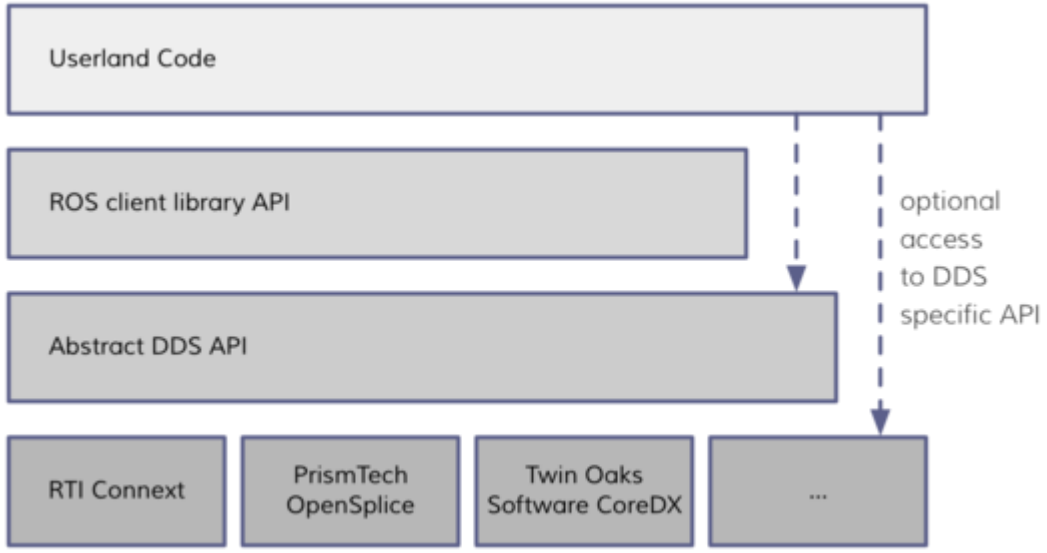
Unicast, Broadcast
Multicast

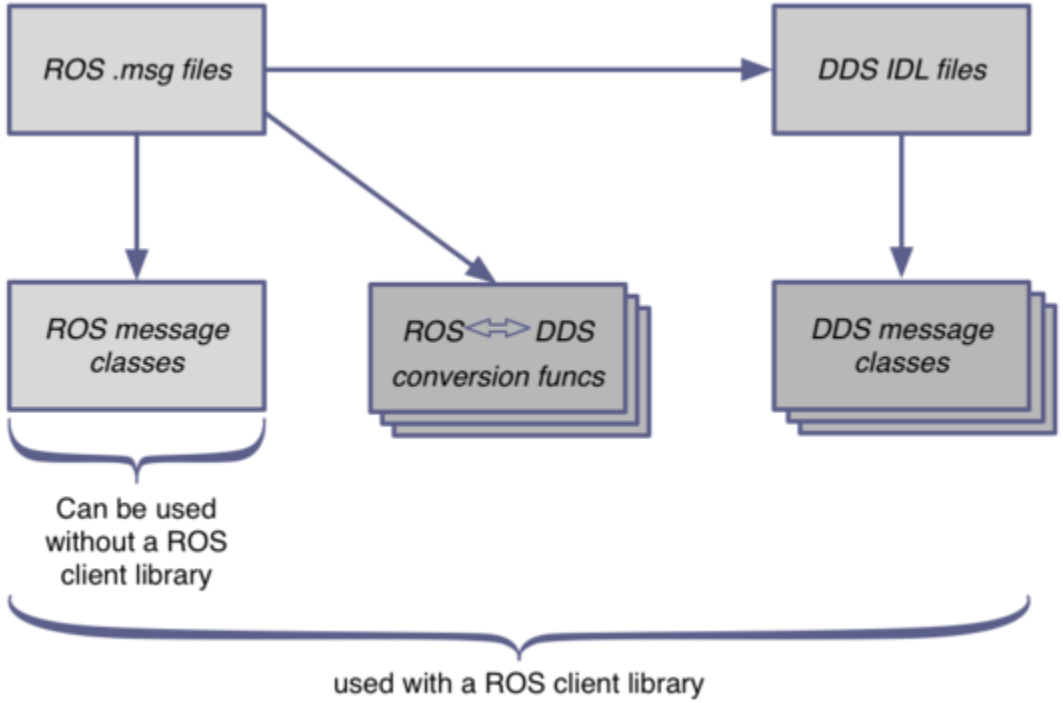
Transport: TCP vs UDP



DDS (Data Distribution Service)

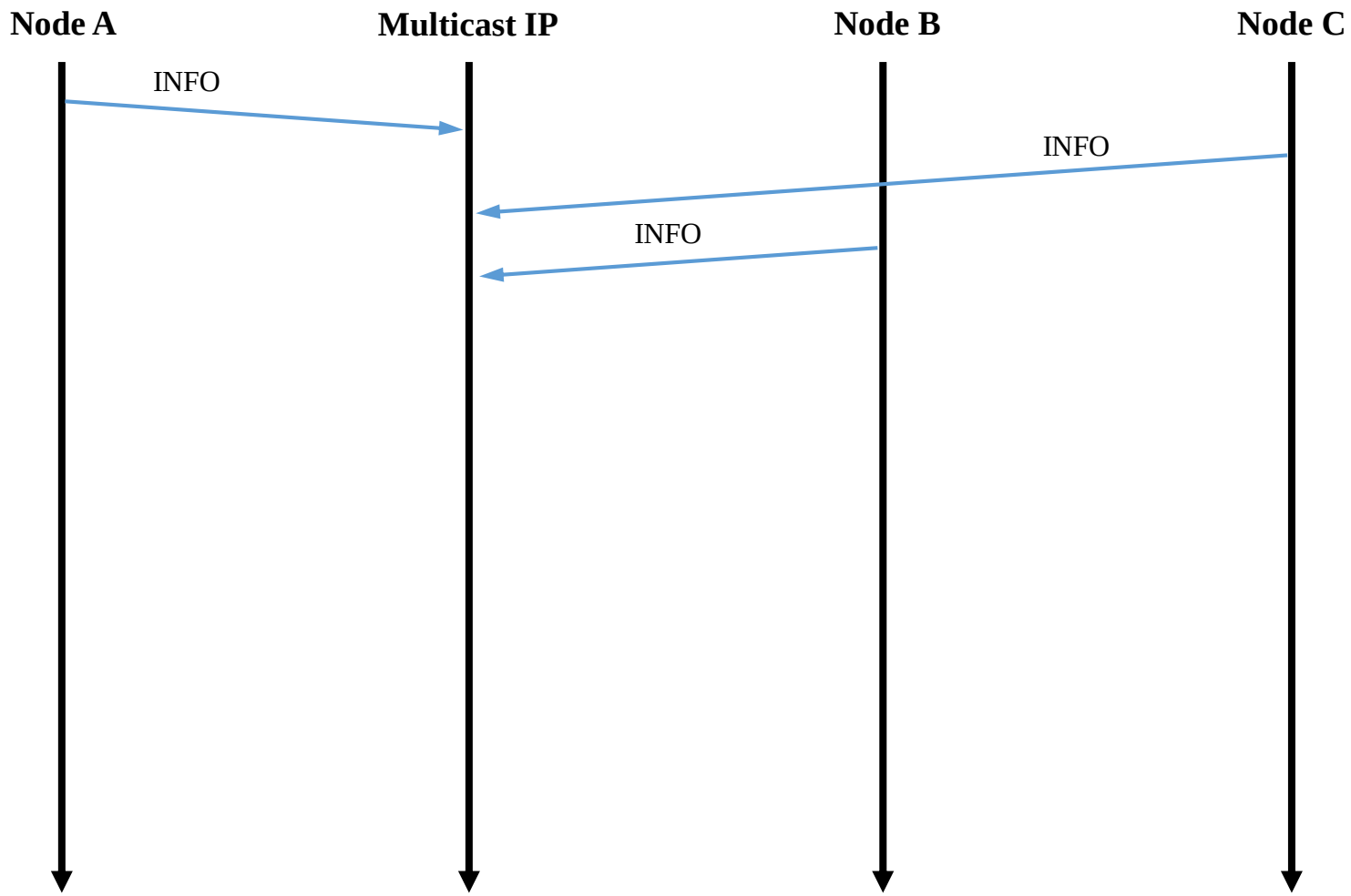
- DDS: 데이터 중심의 분산 시스템의 출판/구독형 미들웨어
  Object Management Group(OMG)가 관리
- 통신 프로토콜: RTPS (Real Time Publish Subscribe)
  UDP기반이지만, TCP의 장점을 가지고 있다.





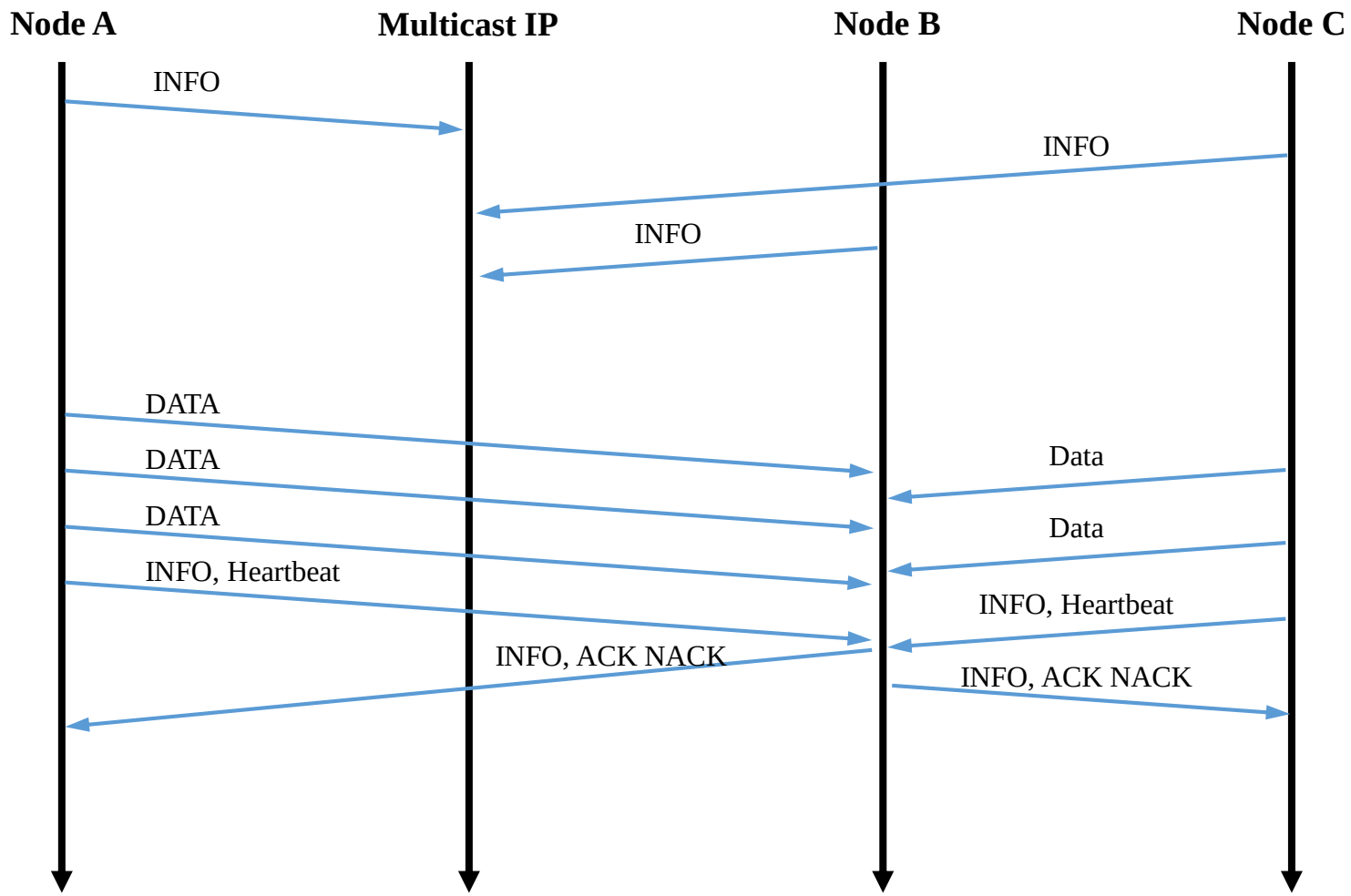
DDS (Data Distribution Service)

- **Auto-Discovery**: No need to know the IP Address and Port number



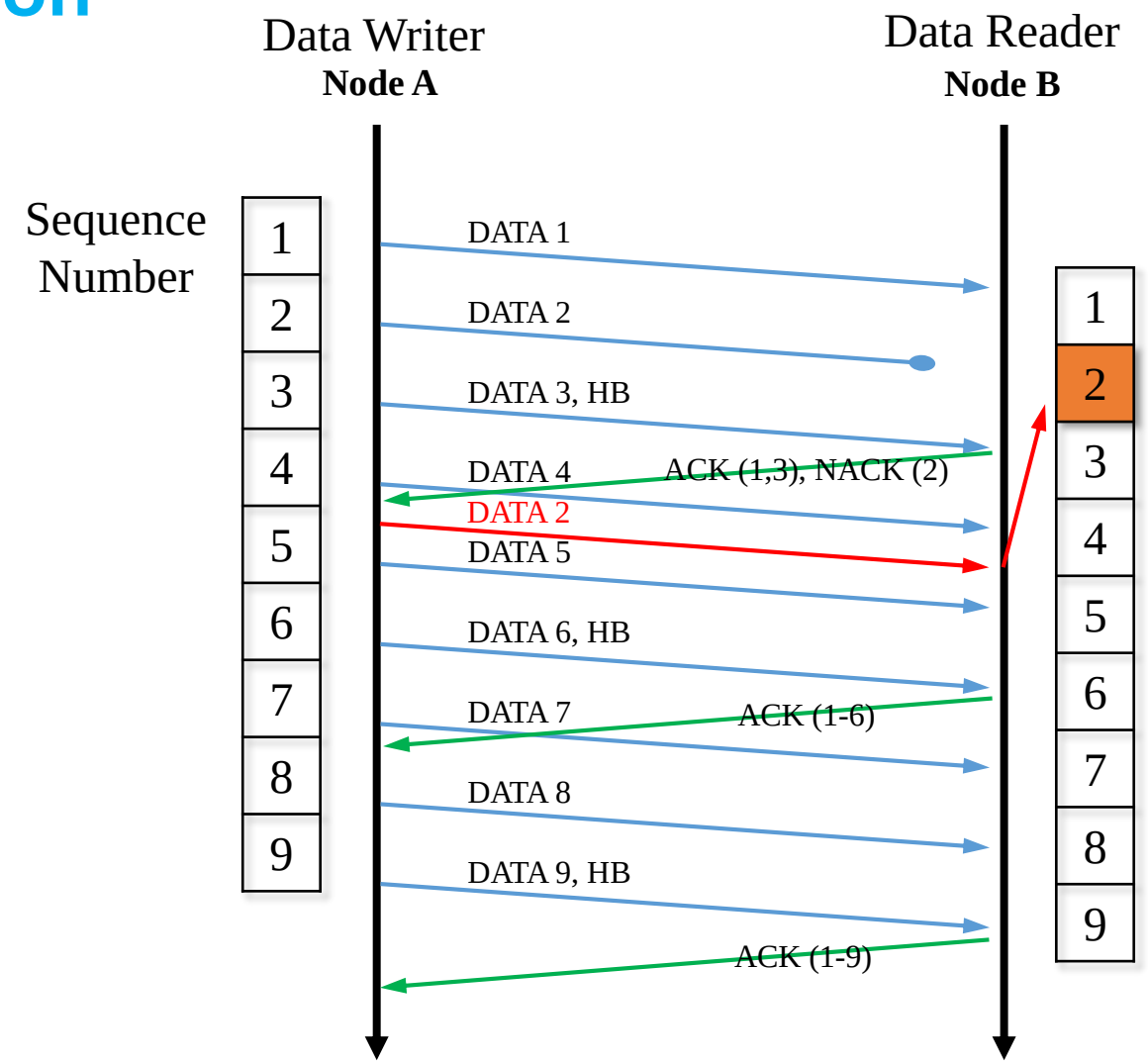
DDS (Data Distribution Service)

- **Auto-Discovery**: No need to know the IP Address and Port number



DDS (Data Distribution Service)

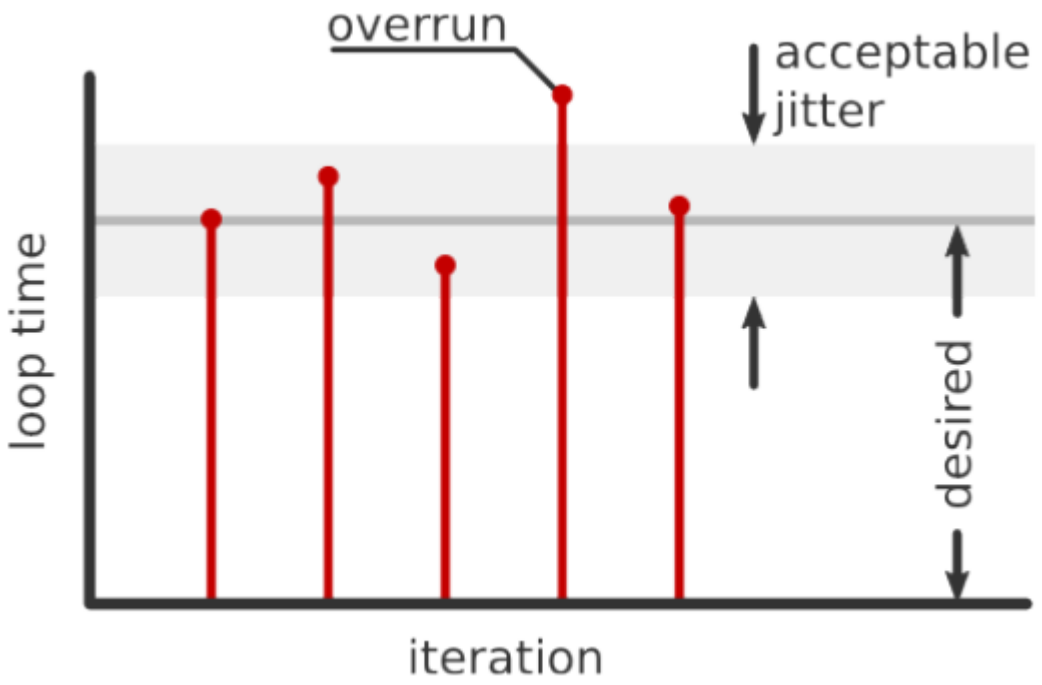
- **Retransmission**



Contents

Real-time Computing

- Real-time: It's about **determinism**, not performance!



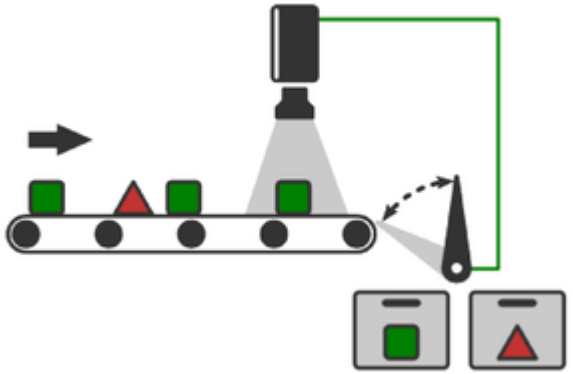
Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

- Hard real-time systems
- Soft real-time systems
- Firm real-time systems

reactor, aircraft, spacecraft control

audio / video streaming



financial forecasting,
robot assembly lines

Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

- Use an OS able to deliver the required determinism

OS	real-time	max latency (µs)
Linux	no	10^4
RT PREEMPT	soft	10^1-10^2
Xenomai	hard	10^1

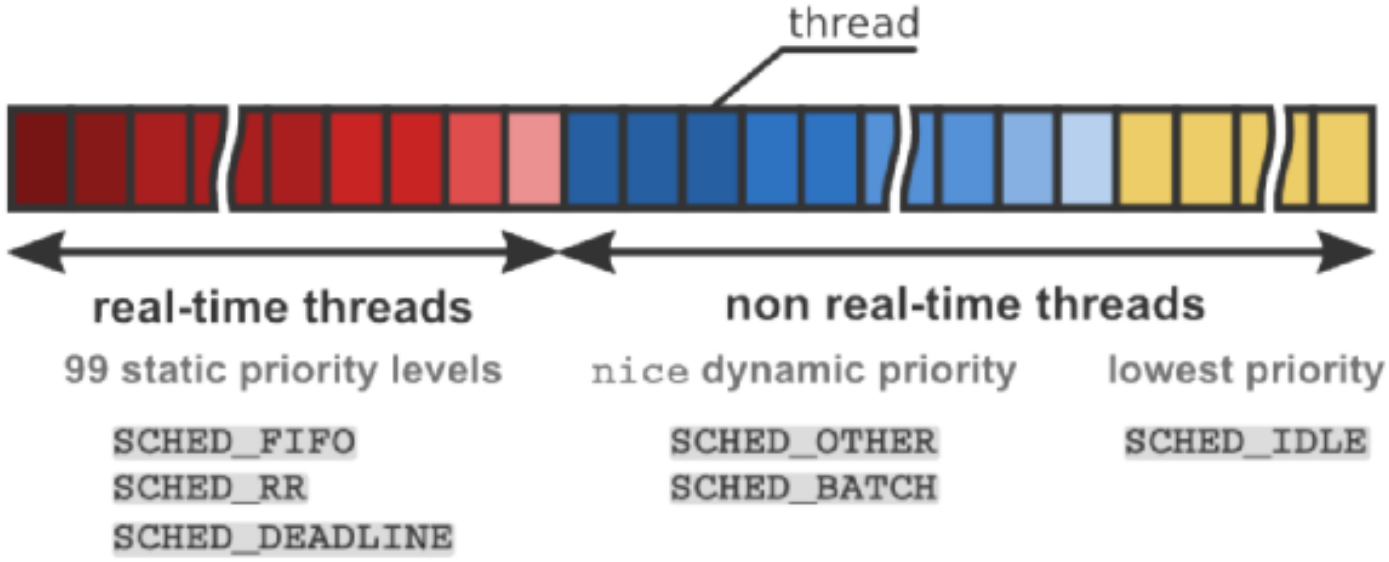
Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

- Use an OS able to deliver the required determinism

OS	real-time	max latency (µs)
Linux	no	10^4
RT PREEMPT	soft	10^1-10^2
Xenomai	hard	10^1

- Prioritize real-time threads



Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

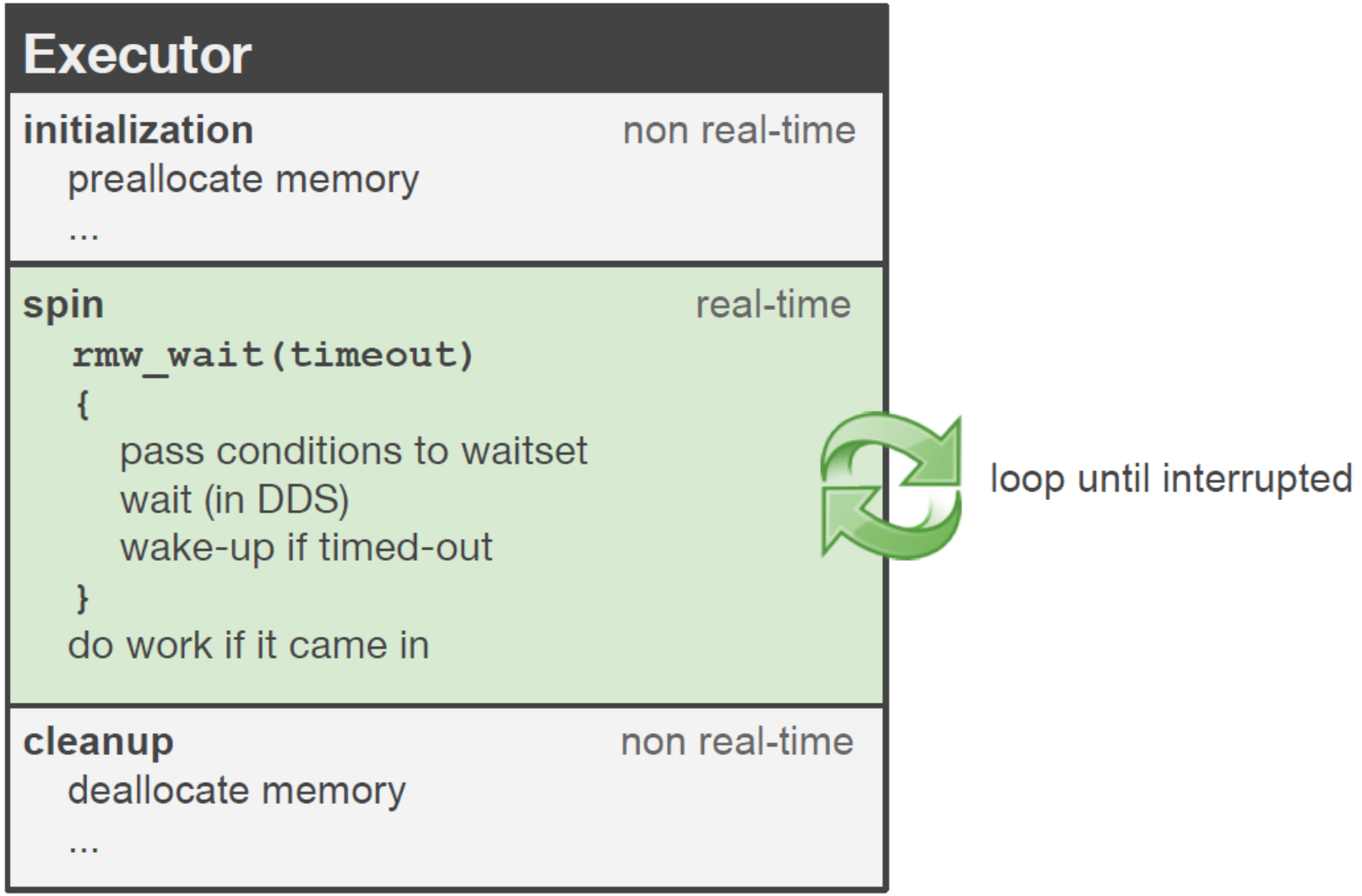
Real-time Computing

- Avoid sources of non-determinism in real-time code
  - Memory allocation and management (malloc, new)
  - Blocking synchronization primitives (mutex)
  - Printing, logging (printf, cout)
  - Network access, especially TCP/IP
  - Non real-time device drivers
  - Accessing the hard disk
  - Page faults

Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

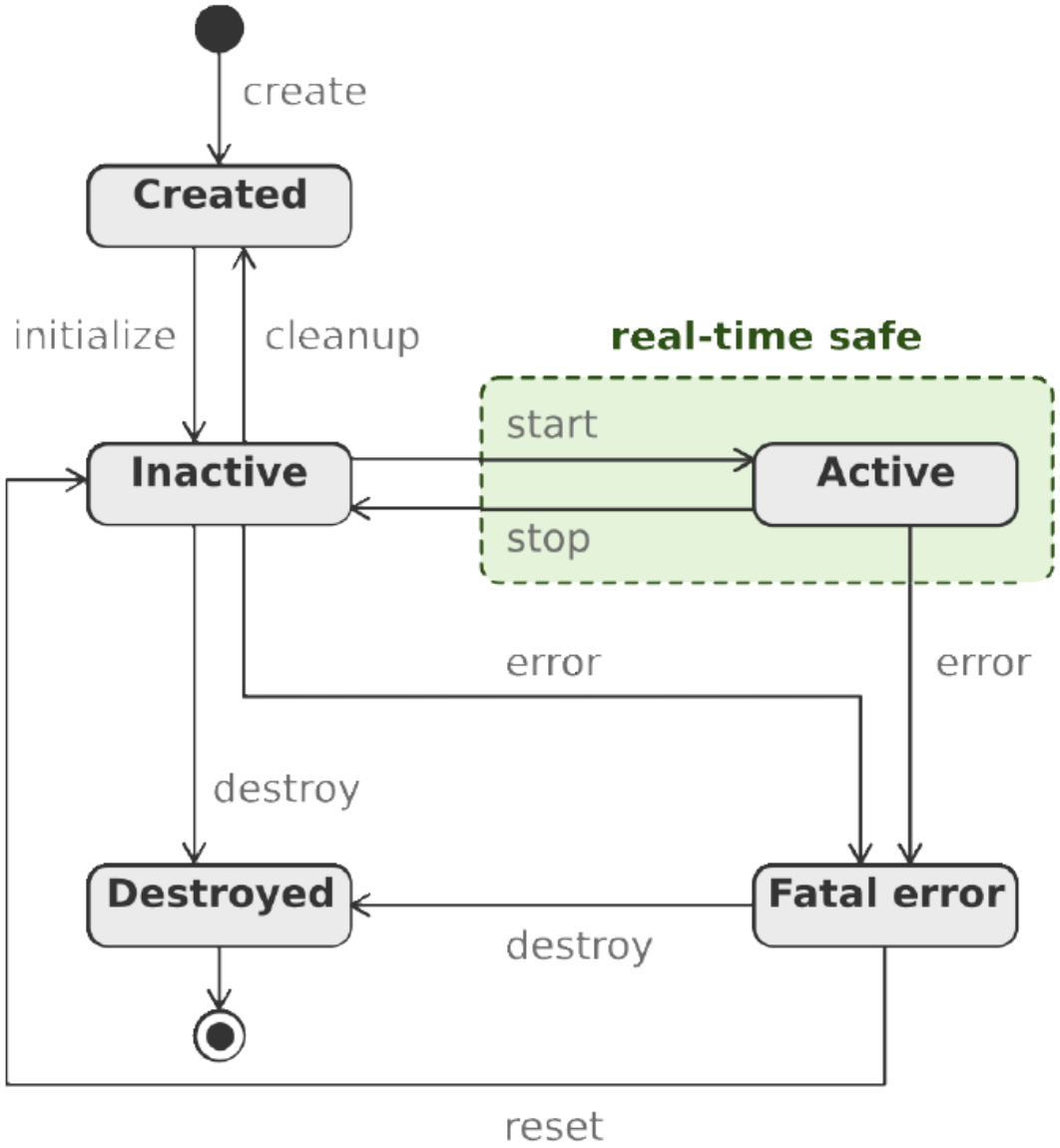
- Real-time code



Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

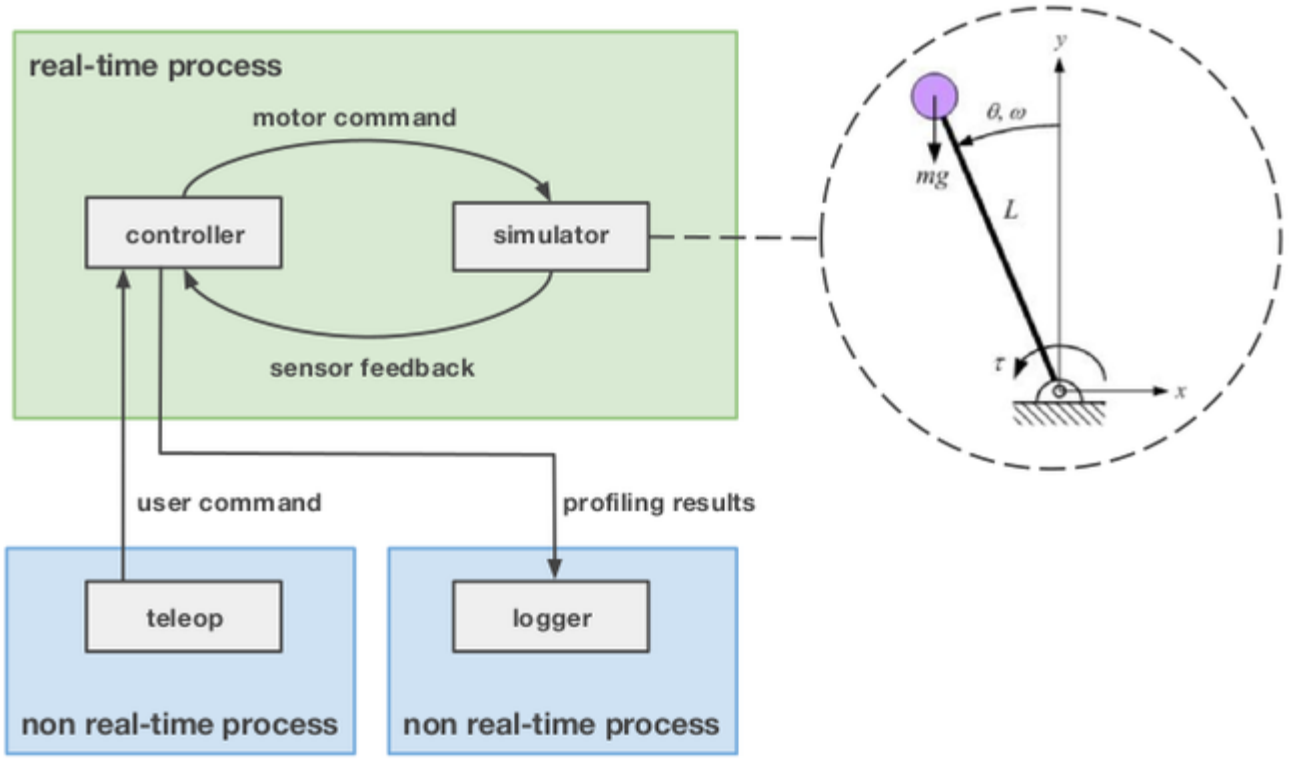
- Node lifecycle



Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

- Real-time Benchmarking



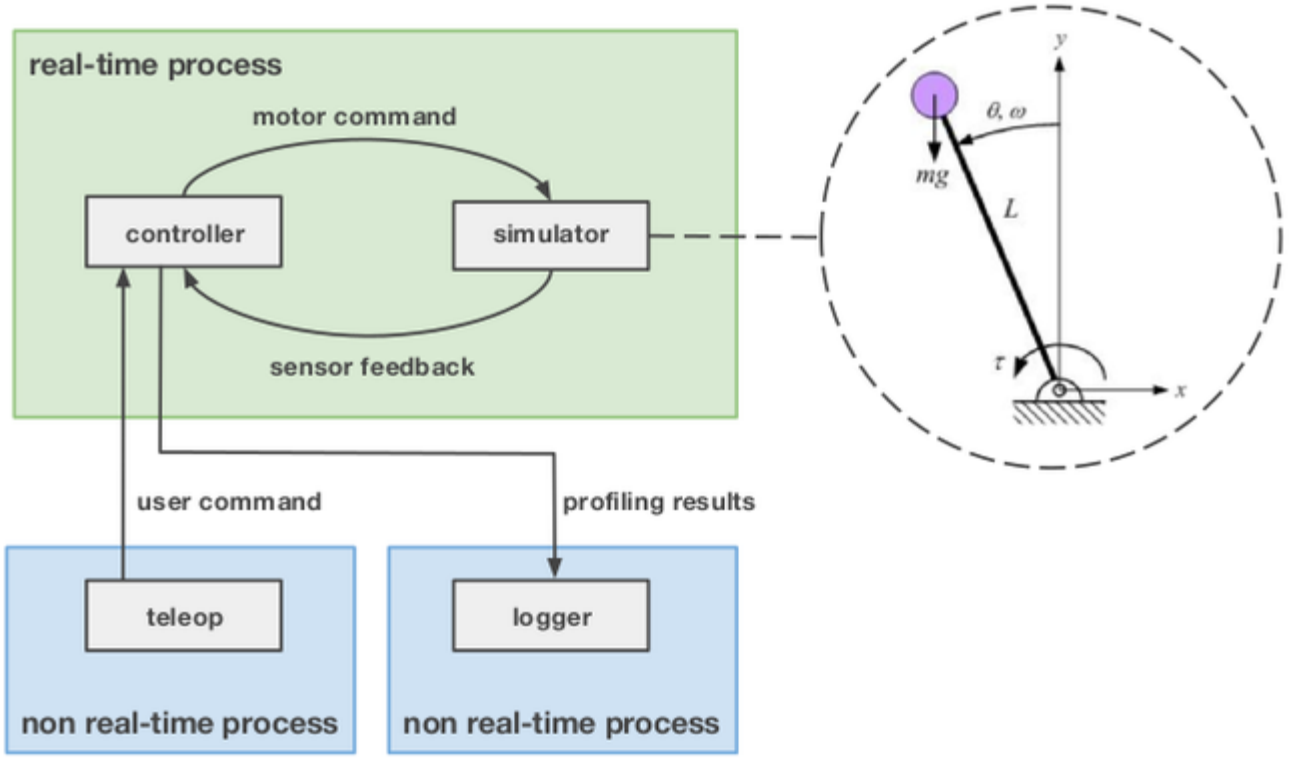
Goal

- **1 KHz** update loop (1 ms period)
- Less than **3%** jitter (30 μs)

Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Real-time Computing

- Real-time Benchmarking



Goal

- **1 KHz** update loop (1 ms period)
- Less than **3%** jitter (30 μs)

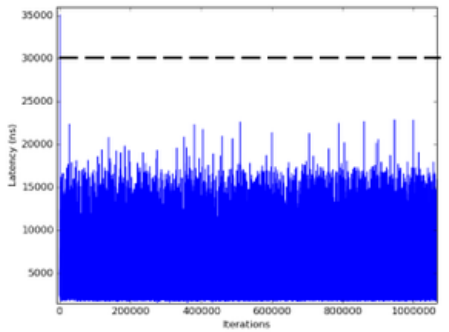
ROS 2 Real-time Benchmarking: Results

No stress

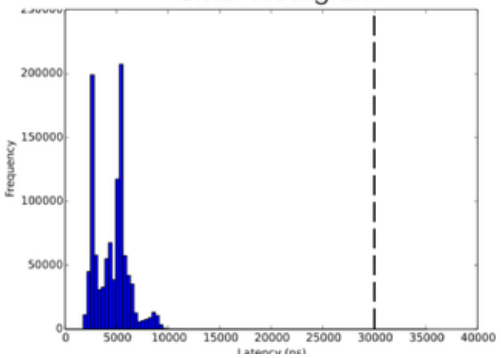
1,070,650 cycles observed

	Latency (ns)	% of update rate
Min	1620	0.16%
Max	35094	3.51%
Mean	4567	0.46%

Timeseries



Jitter histogram

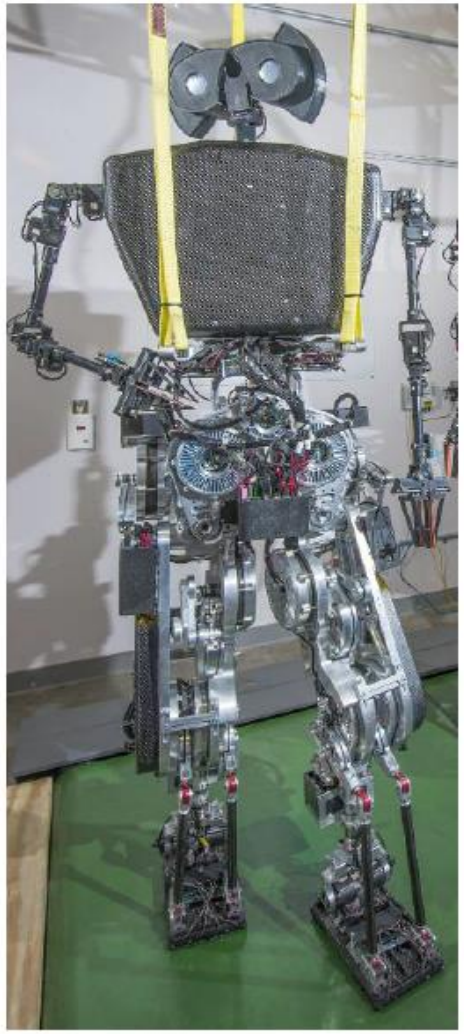


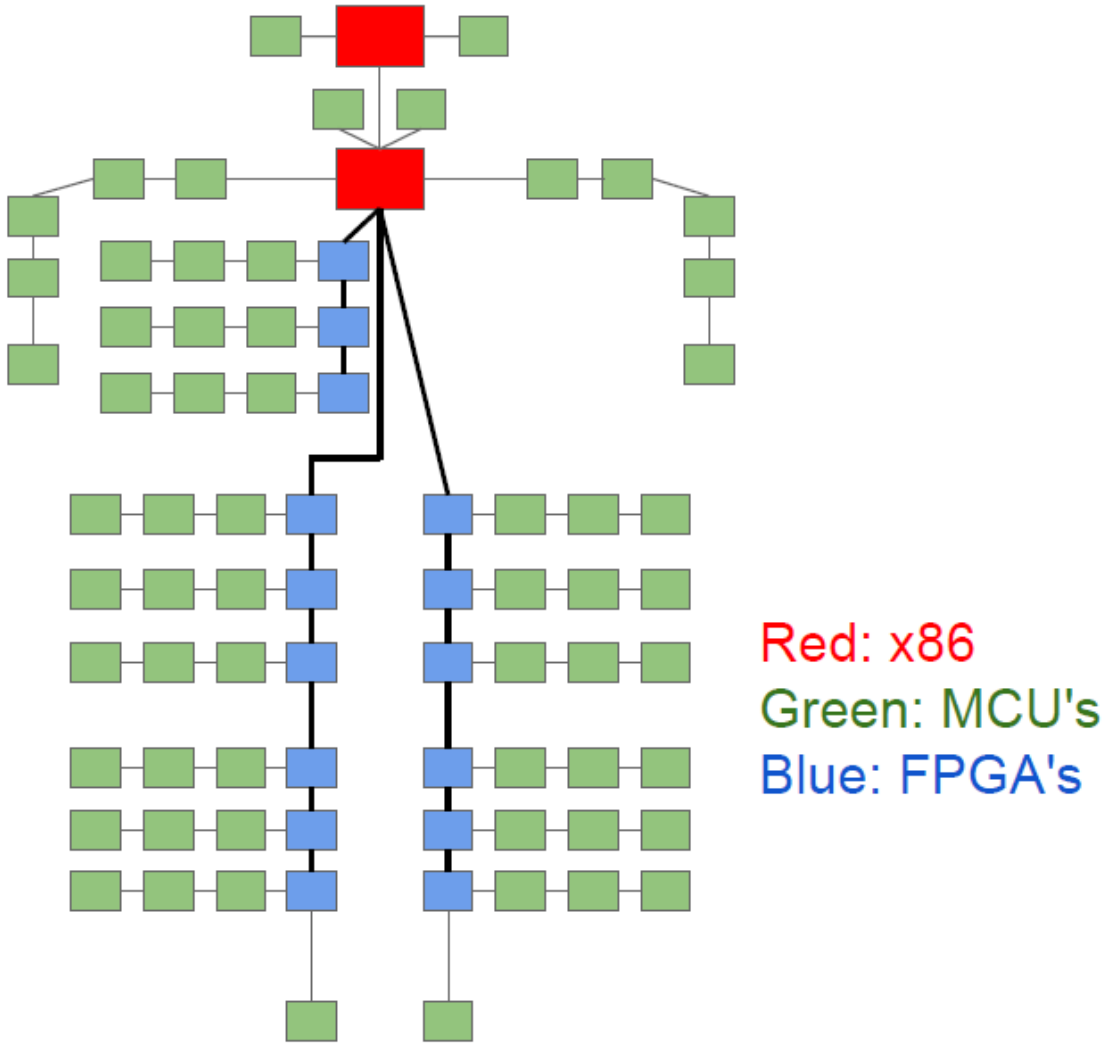
Jackie Kay (OSRF) et. al. "Real-time Performance in ROS 2", ROSCon2015

Contents

Embedded Systems

- Small embedded systems are everywhere!





Morgan Quigley (OSRF) "ROS 2 on ″small″ embedded systems", ROSCon2015

Scope



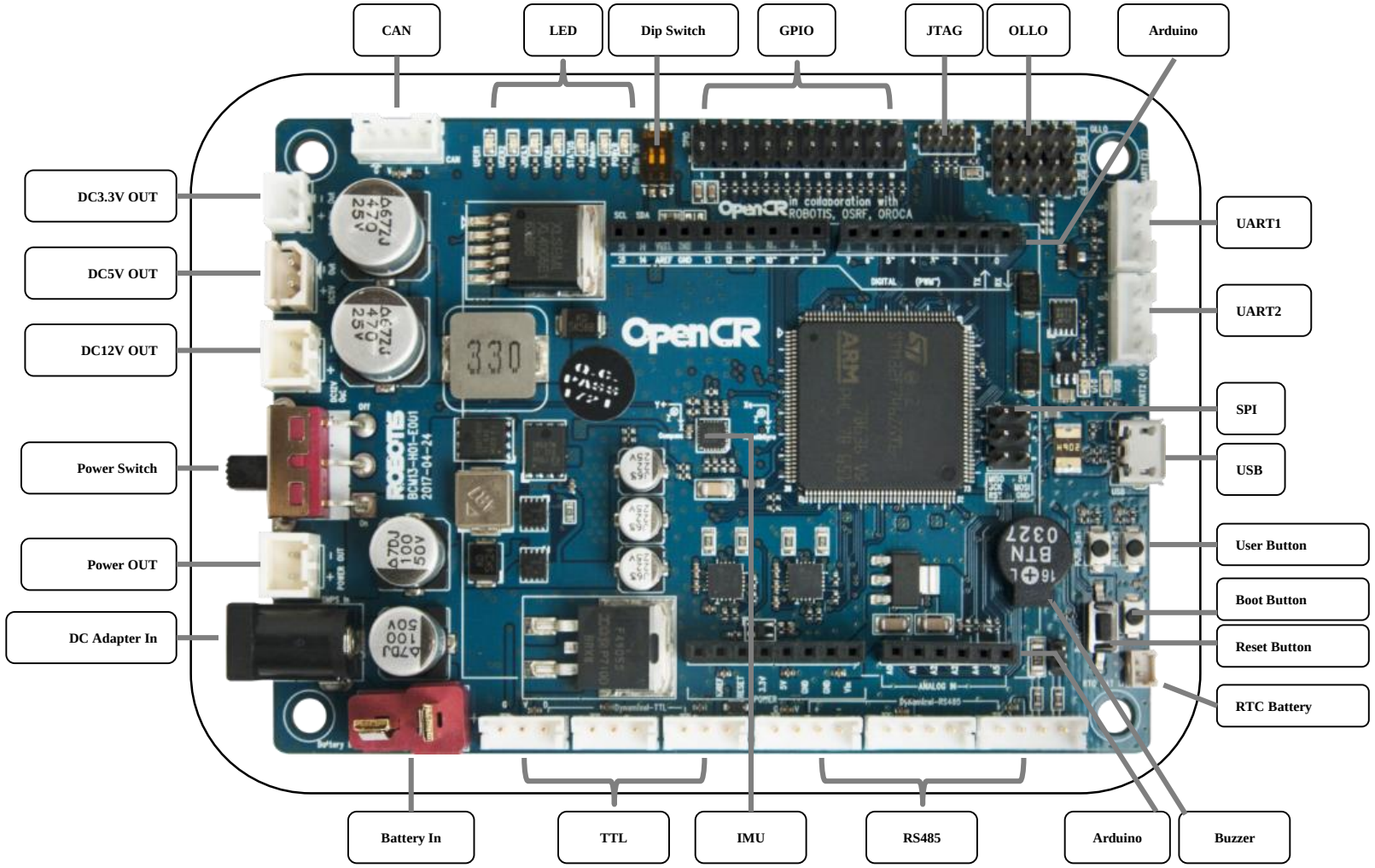

	8/16-bit MCU	32-bit MCU		ARM A-class (smartphone without screen)	x86 (laptop without screen)
		"small" 32-bit MCU	"big" 32-bit MCU		
Example Chip	Atmel AVR	ARM Cortex-M0	ARM Cortex-M7	Samsung Exynos	Intel Core i5
Example System	Arduino Leonardo	Arduino M0 Pro	SAM V71	ODROID	Intel NUC
MIPS	10's	100's	100's	1000's	10000's
RAM	1-32 KB	32 KB	384 KB	a few GB (off-chip)	2-16 GB (SODIMM)
Max power	10's of mW	100's of mW	100's of mW	1000's of mW	10000's of mW
Peripherals	UART, USB FS, ...	USB FS	Ethernet, USB HS	Gigabit Ethernet	USB SS, PCIe

Future work **Target MCU** **"Normal" ROS2**

Morgan Quigley (OSRF) "ROS 2 on ″small″ embedded systems", ROSCon2015

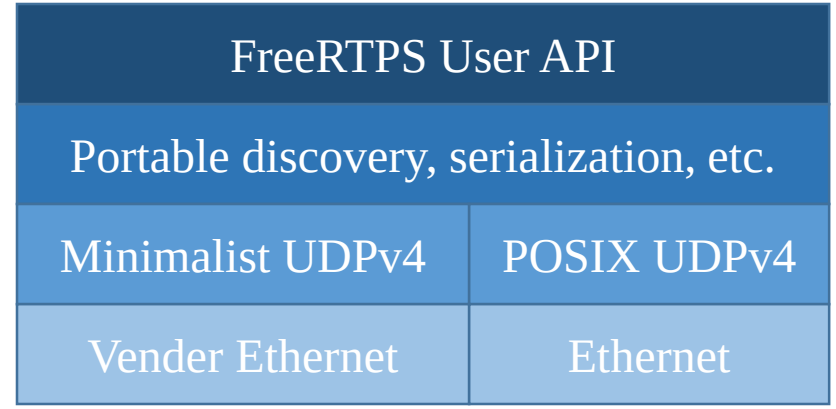
OpenCR

- Open-source Control module for ROS (OpenCR, Link)
- '로스콘 2016'에서 'ROS 임베디드 보드' 발표 (Link)

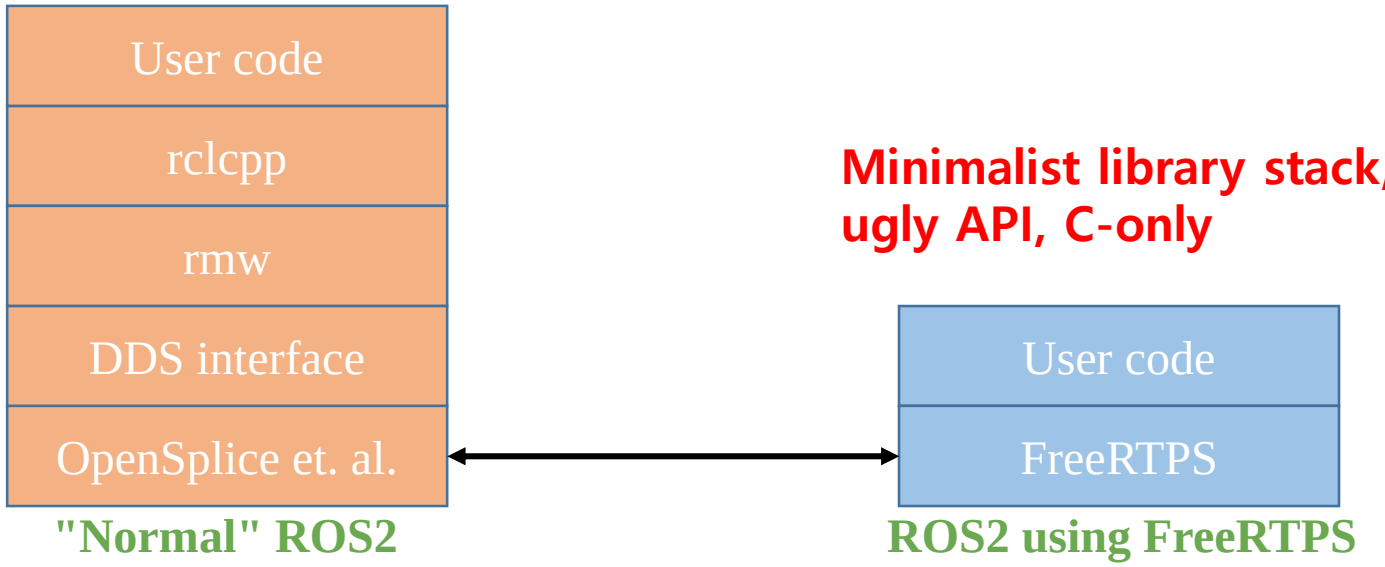


FreeRTPS

- RTPS for embedded systems
- Apache2 License
- https://github.com/ros2/freertps
- It can use on MCU and on Linux.



Flexible library stack, elegant API via C++



Morgan Quigley (OSRF) "ROS 2 on ″small″ embedded systems", ROSCon2015

ROS 2 features for embedded systems

- ROS2 / DDS / RTPS is much more embedded friendly than the ROS1 protocols

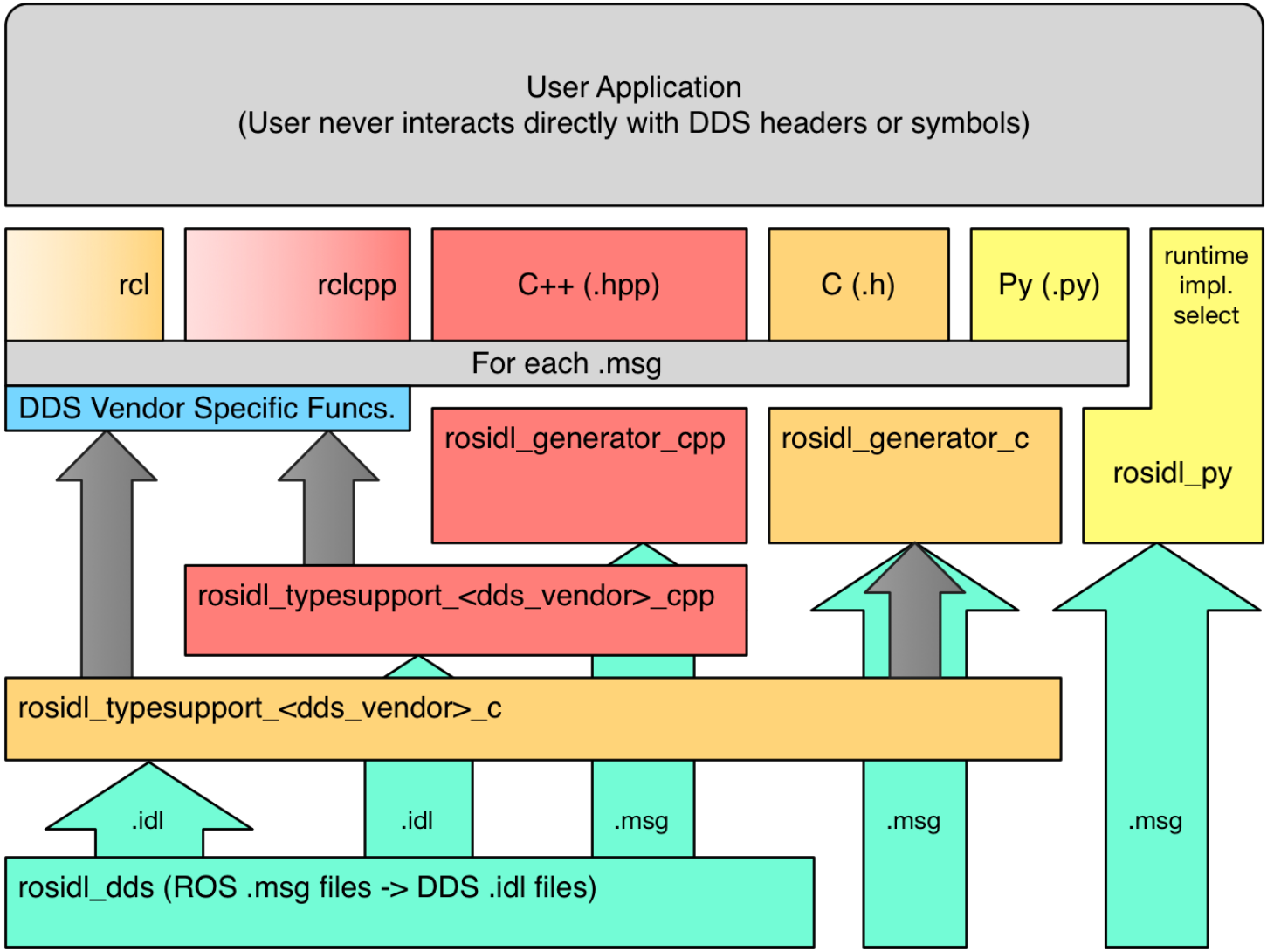
ROS 1	ROS 2
• *startup sequencing*	• *no master*

• *XML-RPC discovery*
  ▫ *parse XML trees*
	• *multicast UDP discovery*
	  ▫ *parse parameter lists*

• *TCP data streams*	• *RTPS/UDP data streams*
• *UDPROS not complete*	• *extensive QoS on UDP*

Morgan Quigley (OSRF) "ROS 2 on ″small″ embedded systems", ROSCon2015

State of ROS 2: Architecture

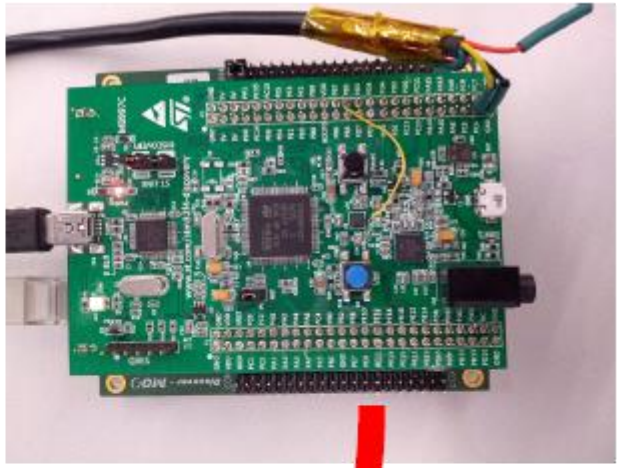


* replace <dds_vendor> with a package for each DDS vendor

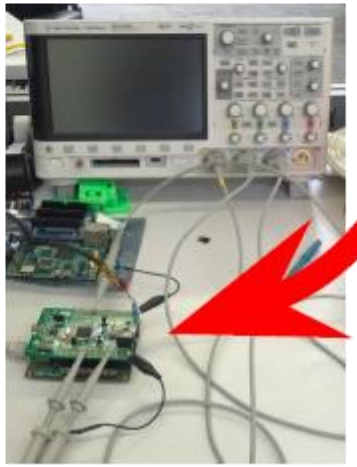
https://github.com/ros2/ros_core_documentation/

Performance measurements: IMU demo

STM32F4-Discovery stack: $55
Slightly modified to use both Ethernet PHY and IMU
Goal: measure FreeRTPS jitter

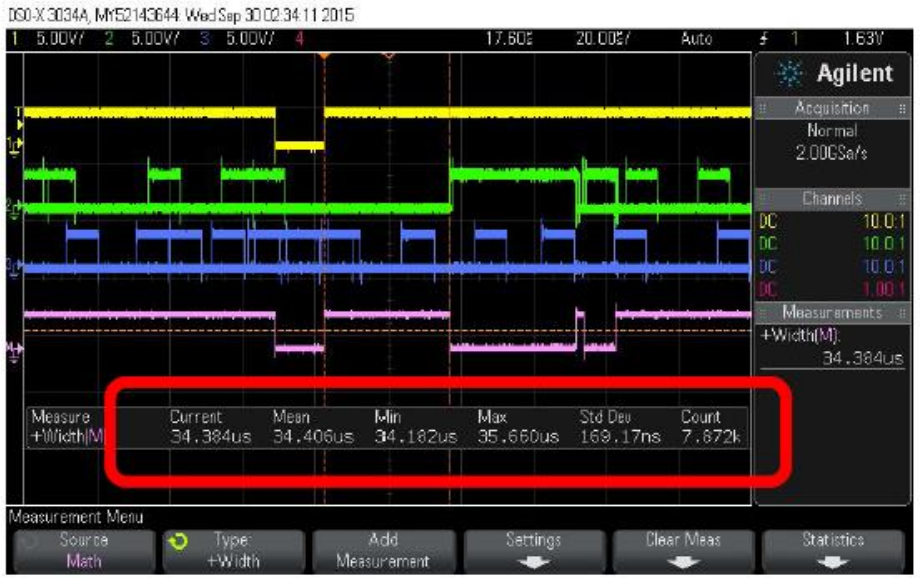


Accelerometer CS and Ethernet TXEN signals to Agilent DSO-X 3034A



IMU CS
Ethernet TXEN
Ethernet RXDV

time calculation



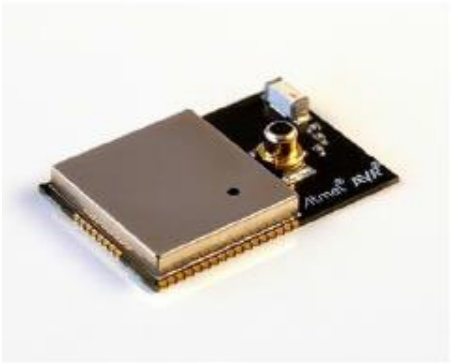
Contents

State of ROS 2

- Goals

Support multi-robot systems involving unreliable networks

Remove the gap between prototyping and final products



"Bare-metal" micro controller

Support for real-time control

Cross-platform support

Dirk Thomas (OSRF) et. al. "State of ROS 2 - demos and the technology behind", ROSCon2015

State of ROS 2: TODO list

- New APIs
- ROS on DDS
- Mapping between ROS interface types and DDS IDL types
- RPC API design in ROS
- Parameter API design in ROS
- ROS 2 middleware interface
- Real-time Systems
- Build system ‘ament’

State of ROS 2: Changes between ROS 1 and ROS 2

	ROS 1	ROS 2
Platforms	Ubuntu, OS X	**Ubuntu, OS X, Windows**
Communication	XMLRPC + ROSTPC	**DDS**
Languages	C++03, Python 2	**C++11, Python 3 (3.5+)**
Build system	rosbuild → catkin	**ament**
Messages, Services	*.msg, *.srv	**new *.msg, *.srv, *.msg.idl, *.srv.idl**
roslaunch	XML	**written in Python**
multiple nodes	one node in a process	**multiple nodes in a process**
real-time	external frameworks like Orocos	**real-time nodes when using a proper RTOS with carefully written user code**
Graph API	remapping at startup time only	**remapping at runtime**
Embedded systems	rosserial (UART)	**FreeRTPS (UART, Ethernet, WiFi, et. al.)**
		No non-isolated build
		No devel space

State of ROS 2: Schedule

- 2015-08-31: ROS 2 Alpha1 release (code name Anchor)
- 2015-11-03: ROS 2 Alpha2 release (code name Baling wire)
- 2015-12-18: ROS 2 Alpha3 release (code name Cement)
- 2016-02-17: ROS 2 Alpha4 release (code name Duct tape)
- 2016-04-06: ROS 2 Alpha5 release (code name Epoxy)
- 2016-06-02: ROS 2 Alpha6 release (code name Fastener)
- 2016-07-14: ROS 2 Alpha7 release (code name Glue Gun)
- 2016-10-04: ROS 2 Alpha8 release (code name Hook-and-Loop)

- 2016-12-19: ROS 2 Beta1 release (code name Asphalt)
- 2017-07-05: ROS 2 Beta2 release (code name R2B2)
- **2017-09-13: ROS 2 Beta3 release**

- **2017-12-13: ROS 2 release**

Contents

미래의 로봇 운영체제가 갖추어야 할 것

- 기능
- 커뮤니티 파워
- 산업용 로봇 벤더들과의 협력
- 하드웨어를 잡아라
- 상업성 확보, 완전한 생태계 구축

미래의 로봇 운영체제가 갖추어야 할 것

- **기능**
  - 대동소이 [大同小異]
  - 처음에는 각각의 특징이 있었으나 닮아가고 서로 보완하고 있다.
  - 기능 갖춤은 필수이지 차별 점이 아니다.
- **커뮤니티 파워**
- **산업용 로봇 벤더들과의 협력**
- **하드웨어를 잡아라**
- **상업성 확보, 완전한 생태계 구축**

미래의 로봇 운영체제가 갖추어야 할 것

- **기능**
  - 대동소이 [大同小異]
  - 처음에는 각각의 특징이 있었으나 닮아가고 서로 보완하고 있다.
  - 기능 갖춤은 필수이지 차별 점이 아니다.
- **커뮤니티 파워**
  - 기능 보강, 빠른 피드백, 컨텐츠 생성, 보급, 문서화, 표준화 등에 큰 도움이 된다.
  - 개발자/사용자 커뮤니티 없는 로봇 운영체제에는 미래란 있을 수 없다.
- **산업용 로봇 벤더들과의 협력**
- **하드웨어를 잡아라**
- **상업성 확보, 완전한 생태계 구축**

미래의 로봇 운영체제가 갖추어야 할 것

● 기능

- 대동소이 [大同小異]
- 처음에는 각각의 특징이 있었으나 닮아가고 서로 보완하고 있다.
- 기능 갖춤은 필수이지 차별 점이 아니다.

● 커뮤니티 파워

- 기능 보강, 빠른 피드백, 컨텐츠 생성, 보급, 문서화, 표준화 등에 큰 도움이 된다.
- 개발자/사용자 커뮤니티 없는 로봇 운영체제에는 미래란 있을 수 없다.

● 산업용 로봇 벤더들과의 협력

- 산업용 로봇의 벤더들은 보유 기술은 공개할 수 없지만 산학협력은 해야 한다.
- 오월동주 [吳越同舟] (ROS-Industrial)

● 하드웨어를 잡아라

● 상업성 확보, 완전한 생태계 구축

미래의 로봇 운영체제가 갖추어야 할 것

- **기능**
  - 대동소이 [大同小異]
  - 처음에는 각각의 특징이 있었으나 닮아가고 서로 보완하고 있다.
  - 기능 갖춤은 필수이지 차별 점이 아니다.
- **커뮤니티 파워**
  - 기능 보강, 빠른 피드백, 컨텐츠 생성, 보급, 문서화, 표준화 등에 큰 도움이 된다.
  - 개발자/사용자 커뮤니티 없는 로봇 운영체제에는 미래란 있을 수 없다.
- **산업용 로봇 벤더들과의 협력**
  - 산업용 로봇의 벤더들은 보유 기술은 공개할 수 없지만 산학협력은 해야 한다.
  - 오월동주 [吳越同舟] (ROS-Industrial)
- **하드웨어를 잡아라**
  - 하드웨어 추상화 플랫폼 실현, 표준/규격 제안, 모듈화 하드웨어 유도
- **상업성 확보, 완전한 생태계 구축**

미래의 로봇 운영체제가 갖추어야 할 것

● 기능

- 대동소이 [大同小異]
- 처음에는 각각의 특징이 있었으나 닮아가고 서로 보완하고 있다.
- 기능 갖춤은 필수이지 차별 점이 아니다.

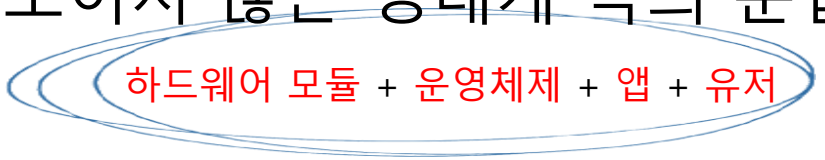
● 커뮤니티 파워

- 기능 보강, 빠른 피드백, 컨텐츠 생성, 보급, 문서화, 표준화 등에 큰 도움이 된다.
- 개발자/사용자 커뮤니티 없는 로봇 운영체제에는 미래란 있을 수 없다.

● 산업용 로봇 벤더들과의 협력

- 산업용 로봇의 벤더들은 보유 기술은 공개할 수 없지만 산학협력은 해야 한다.
- 오월동주 [吳越同舟] (ROS-Industrial)

보이지 않는 생태계 속의 분업



● 하드웨어를 잡아라

- 하드웨어 추상화 플랫폼 실현, 표준/규격 제안, 모듈화 하드웨어 유도

● 상업성 확보, 완전한 생태계 구축

- ROS는 아카데믹적인 면에서 영향력을 발휘했지만 수익 면에서는 NAOqi 처럼 개발자의 수익도 염두 해둔 APP시장을 키워야 더욱 풍부한 응용 애플리케이션 개발을 이끌 수 있다.
- 생태계 (ECO system)

질문
대환영!

* 온라인 상의 질문이라면
오르카 및 로열로를 이용해주세요!

여기서! 광고 하나 나가요~

개정 증보판

✔ 한국어판 구매 링크

✔ 4개 언어로 출판!

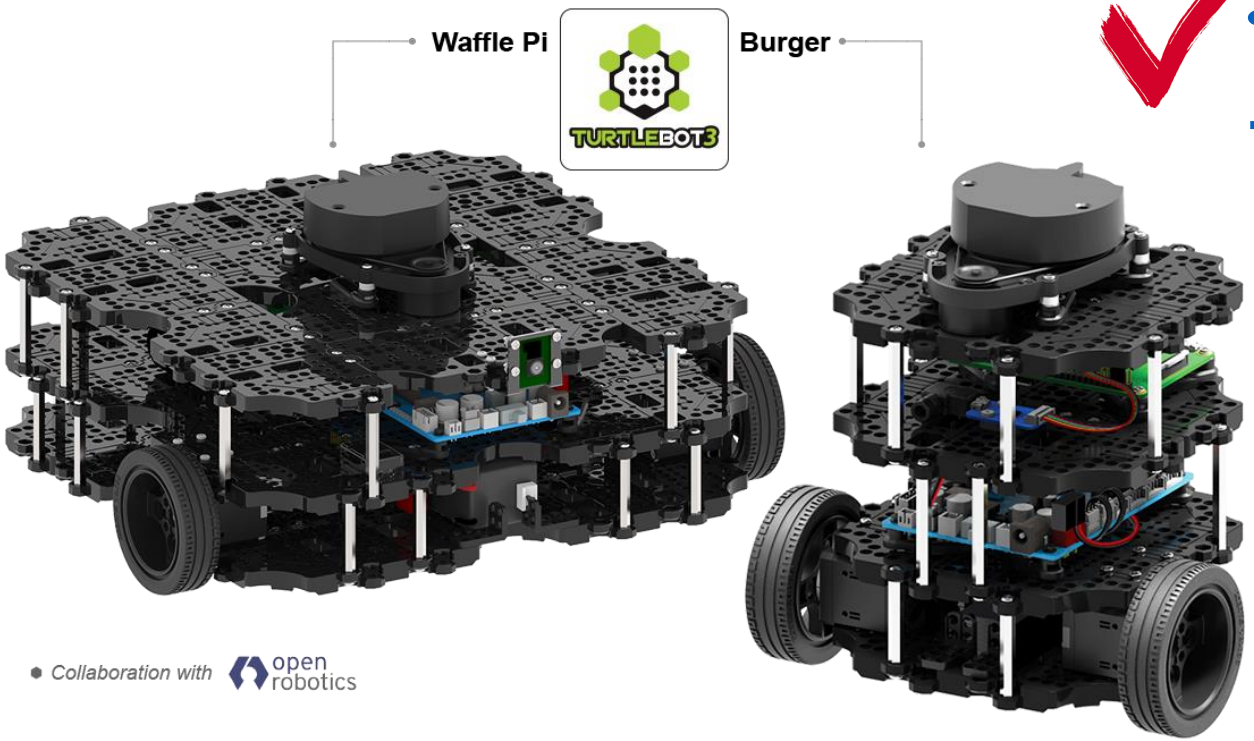
국내 유일! 최초! ROS 참고서!
ROS 공식 플랫폼 **TurtleBot3** 개발팀이
직접 저술한 바이블급 ROS 책

여기서! 광고 둘 나가요~

TURTLEBOT3

인공지능(AI) 연구의 시작,
ROS 교육용 공식 로봇 플랫폼

터틀봇3는 ROS기반의 저가형 모바일 로봇으로 교육, 연구, 제품개발, 취미 등 다양한 분야에서 활용할 수 있습니다.



Direct Link

여기서! 광고 셋 나가요~

오로카

- 오로카
- www.oroca.org
- 오픈 로보틱스 지향
- 풀뿌리 로봇공학의 저변 활성화
- 공개 강좌, 세미나, 프로젝트 진행

- 로봇공학을 위한 열린 모임 (KOS-ROBOT)
- www.facebook.com/groups/KoreanRobotics
- 로봇공학 통합 커뮤니티 지향
- 일반인과 전문가가 어울러지는 한마당
- 로봇공학 정보 공유
- 연구자 간의 협력

Robot Source

- RobotSource
- www.robotsource.org
- 글로벌 로보틱스 커뮤니티 지향
- 로봇공학 정보 공유
- 자신의 로봇 프로젝트 공유
- DIY 로봇 프로젝트 진행

혼자 하기에 답답하시다고요?

커뮤니티에서 함께 해요~

끝.

표윤석

Yoonseok Pyo
pyo@robotis.com
www.robotpilot.net

www.facebook.com/yoonseok.pyo