



OVERVIEW OF ROS

ANIS KOUBAA

What is and Why ROS?

<https://www.udemy.com/user/anis-koubaa/>

2020

My Udemy Courses



ROS for Beginners: Basics, Motion, and OpenCV

Anis Koubaa

4.2 ★★★★☆ (1,994)

11 total hours • 99 lectures • Beginner



ROS for Beginners II: Localization, Navigation and SLAM

Anis Koubaa

4.3 ★★★★☆ (440)

3.5 total hours • 66 lectures • Intermediate



ROS2 (Foxy) How To: Discover Next Generation ROS

Anis Koubaa

4.0 ★★★★☆ (133)

Learning Path



ROS for Beginners: Basics, Motion, and OpenCV

Anis Koubaa

4.2 ★★★★☆ (1,994)

11 total hours • 99 lectures • Beginner



Learning Path



**ROS for Beginners II: Localization,
Navigation and SLAM**

Anis Koubaa

4.3 ★★★★☆ (440)

3.5 total hours • 66 lectures • Intermediate

ROS TRANSFORMATIONS

REACTIVE NAVIGATION

MAP-BASED NAVIGATION

AERIAL ROBOTS

Learning Path





LEARNING OUTCOMES

Learning Outcome

- ▶ Understand ROS Ecosystem (topics, nodes, messages, services, actionlib)
- ▶ Develop simple applications to control robot motion
- ▶ Understand how a position and orientation are represented in ROS
- ▶ Recognize how to develop a C++/Python ROS project
- ▶ Develop simple computer vision programs with ROS and OpenCV
- ▶ Develop application for robot navigation

Development Environment

- ▶ ROS Melodic on Ubuntu 18.04 (VM or Physical Machine)
- ▶ Laptop recommended requirements
 - ▶ 8 GB of RAM
 - ▶ SSD Hard drive



WHY ROS?

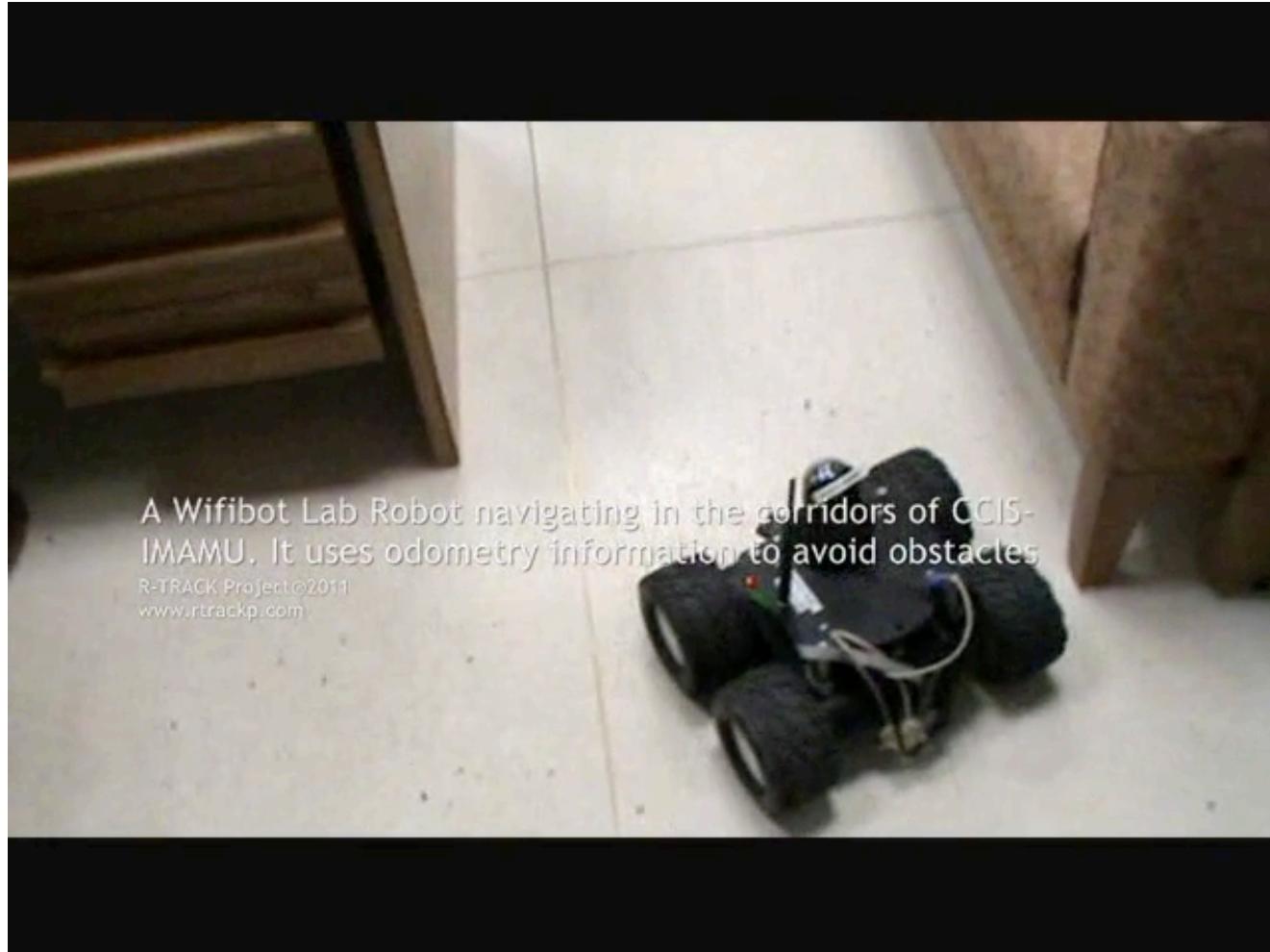
Robot Path Planning

2010



Robot Navigation

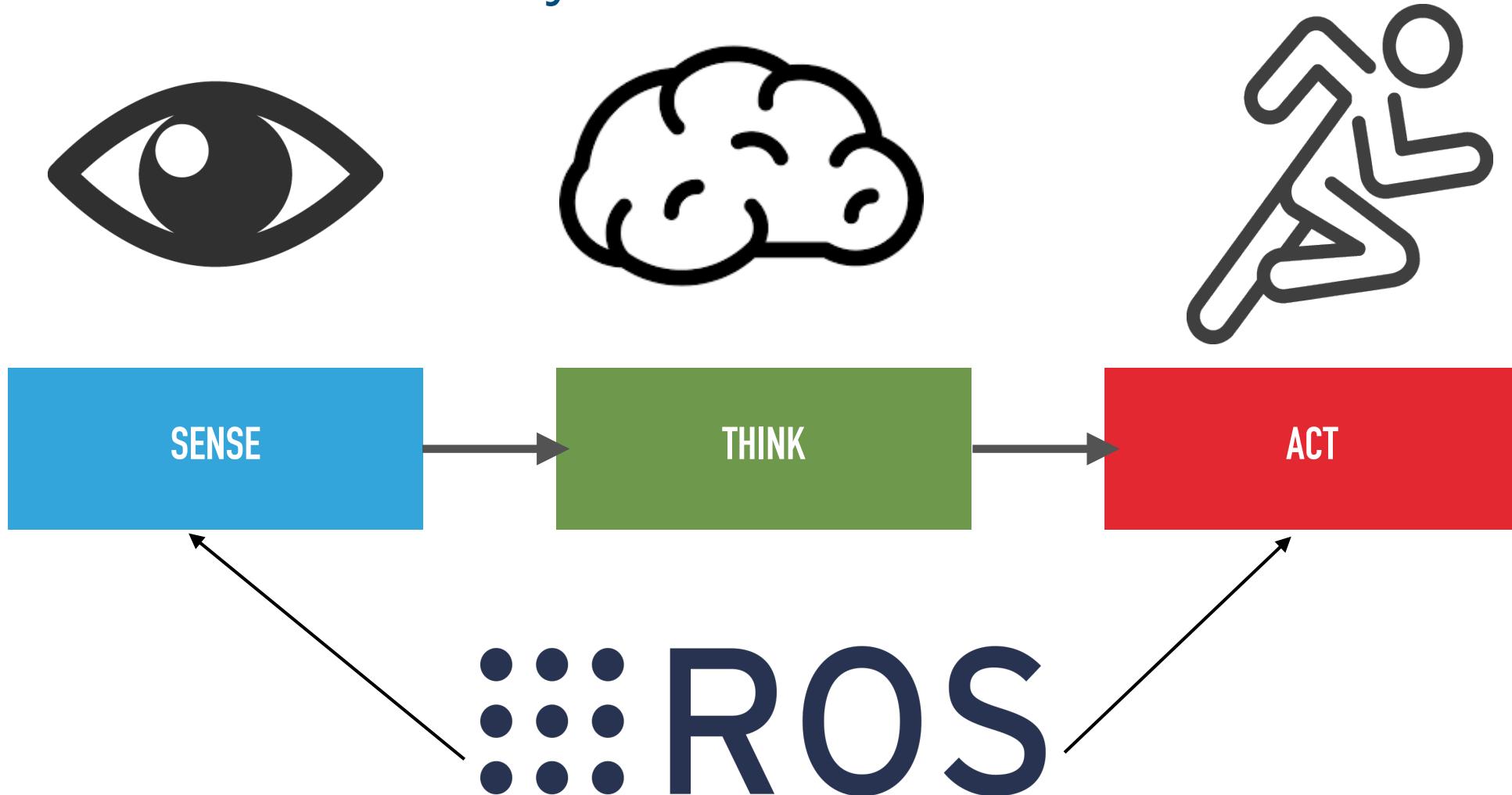
2010



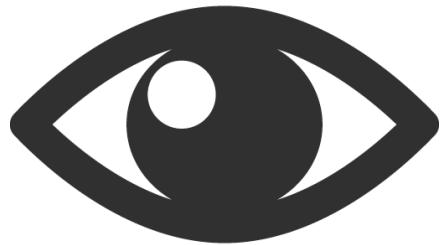
Flying a Drone



Robot Process Cycle



Sense



SENSE

CAMERA



LASERS



ULTRASONIC



GPS

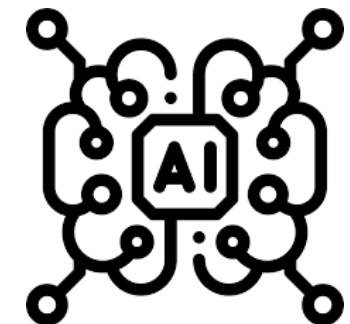


Think

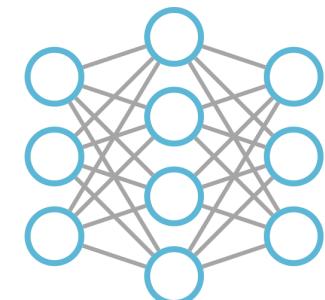


THINK

ARTIFICIAL INTELLIGENCE



MACHINE LEARNING



SIGNAL PROCESSING



Act



ACT

BRUSHLESS MOTORS



UAV MOTORS



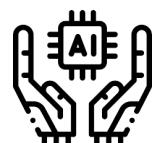
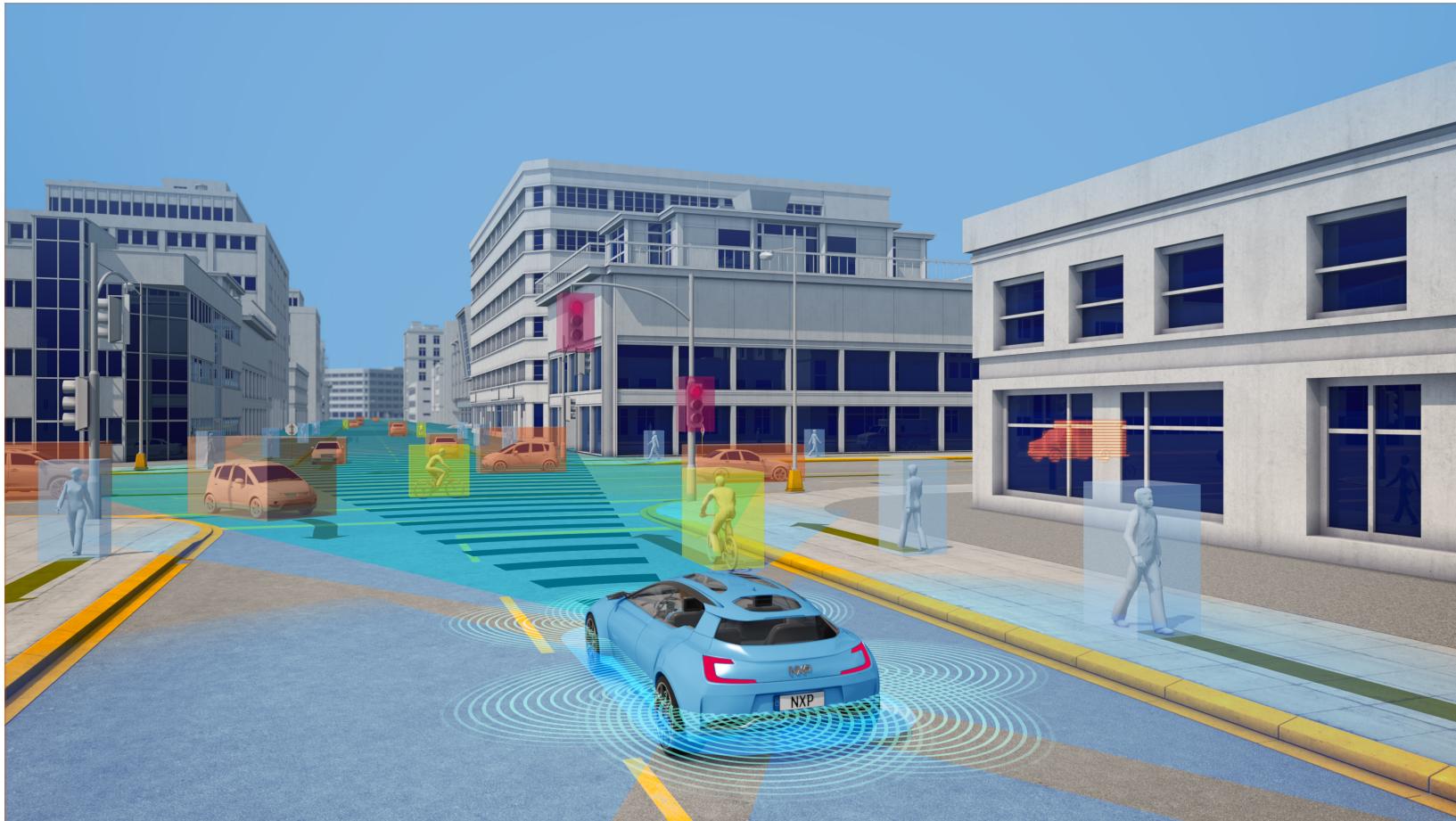
ACTUATORS



SERVOS



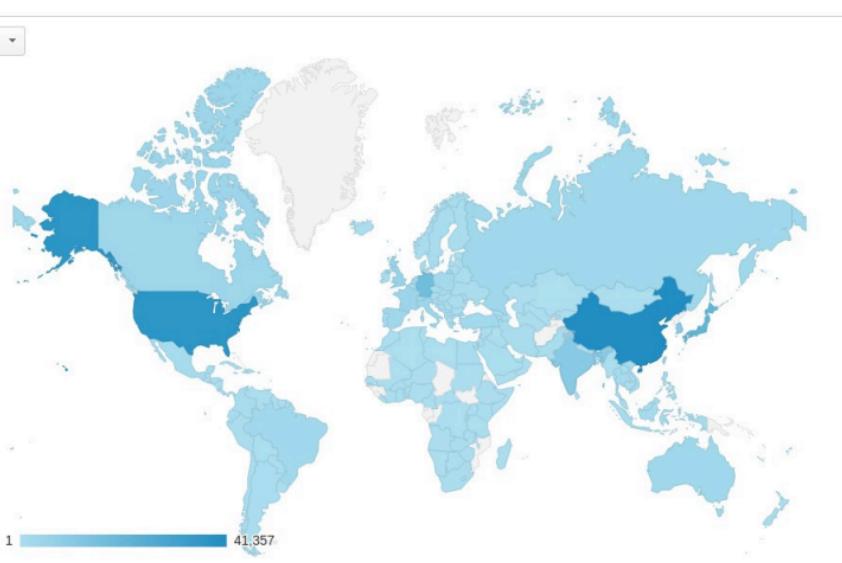
Self-Driving Car



ROS Impact

1. 🇨🇳 China	41,357 (19.88%)
2. 🇺🇸 United States	36,531 (17.56%)
3. 🇯🇵 Japan	19,738 (9.49%)
4. 🇩🇪 Germany	15,525 (7.46%)
5. 🇰🇷 South Korea	9,382 (4.51%)
6. 🇮🇳 India	9,345 (4.49%)
7. 🇬🇧 United Kingdom	4,972 (2.39%)
8. 🇮🇹 Taiwan	4,856 (2.33%)
9. 🇫🇷 France	4,056 (1.95%)
10. 🇨🇦 Canada	3,854 (1.85%)
11. 🇸🇬 Singapore	3,516 (1.69%)
12. 🇮🇹 Italy	3,464 (1.66%)
13. 🇷🇺 Russia	3,207 (1.54%)
14. 🇦🇺 Australia	3,114 (1.50%)
15. 🇪🇸 Spain	3,080 (1.48%)
16. 🇭🇰 Hong Kong	2,941 (1.41%)
17. 🇧🇷 Brazil	2,548 (1.22%)
18. 🇹🇷 Turkey	2,253 (1.08%)
19. 🇳🇱 Netherlands	1,822 (0.88%)
20. 🇵🇱 Poland	1,820 (0.87%)
21. 🇵🇭 Philippines	1,711 (0.82%)
22. 🇲🇭 Thailand	1,585 (0.76%)
23. 🇨🇭 Switzerland	1,478 (0.71%)
24. (not set)	1,429 (0.69%)
25. 🇮🇩 Indonesia	1,345 (0.65%)

wiki.ros.org visitor locations:



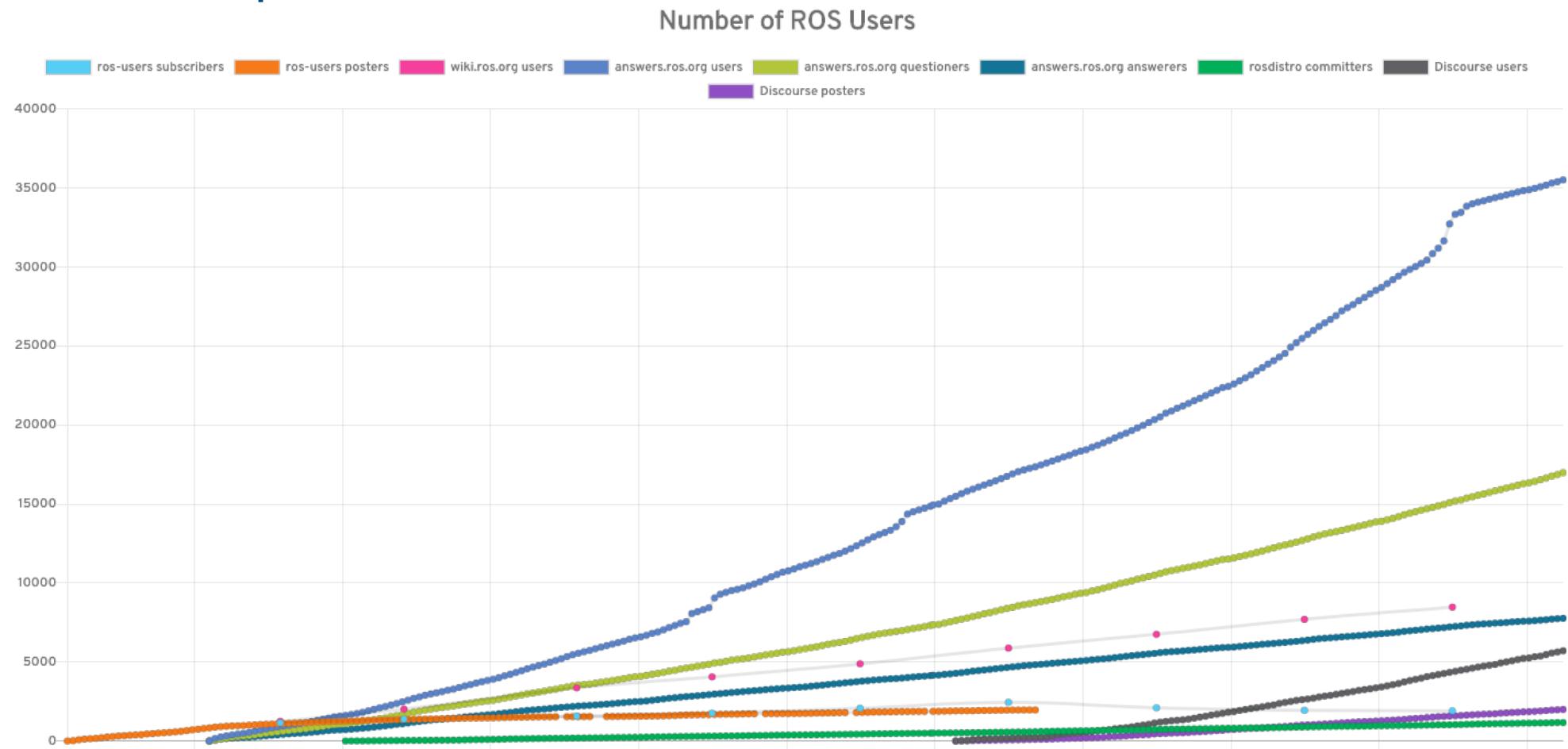
Source: Google Analytics
Site: wiki.ros.org in July 2019

2M Page View per Month
120000 new users per month

6

SOURCE <http://download.ros.org/downloads/metrics/metrics-report-2019-07.pdf>

ROS Impact



SOURCE: https://metrics.ros.org/analytics_pageviews.html



WHAT IS ROS?

ROS (1) Evolution

- May 23, 2018 - ROS Melodic
- Dec 08, 2017 - Release of ROS 2.0
- Sep 21, 2017 - ROSCon2017 (Canada)
- May 23, 2017 - Release of Lunar Loggerhead
- May 16, 2017 - Changed name from OSRF to Open Robotics
- Oct 8, 2016 - ROSCon2016 (South Korea)
- May 23, 2016 - Release of Kinetic Kame
- Oct 3, 2015 - ROSCon2015 (Germany)
- May 23, 2015 - Release of Jade Turtle
- Sep 12, 2014 - ROSCon2014 Conference (U.S.)
- Jul 22, 2014 - Release of Indigo Igloo
- Jun 6, 2014 - ROS Kong 2014 Conference (Hong Kong)
- Sep 4, 2013 - Release of Hydro Medusa
- May 11, 2013 - ROSCon2013 Conference (Germany)
- Feb 11, 2013 - Open Source Robotics Foundation takes on development/management
- Dec 31, 2012 - Release of Groovy Galapagos
- May 19, 2012 - ROSCon2012 Conference (U.S.)
- Apr 23, 2012 - Release of Fuerte
- Aug 30, 2011 - Release of Electric Emys
- Mar 2, 2011 - Release of Diamondback
- Aug 2, 2010 - Release of C Turtle
- Mar 2, 2010 - Release of Box Turtle
- Jan 22, 2010 - Release of ROS 1.0
- Nov 1, 2007 - Willow Garage starts development under the name 'ROS'
- May 1, 2007 - Switchyard Project, Morgan Quigley, Stanford AI LAB, Stanford University
- 2000 - Player/Stage Project, Brian Gerkey, University of Southern California (USC)

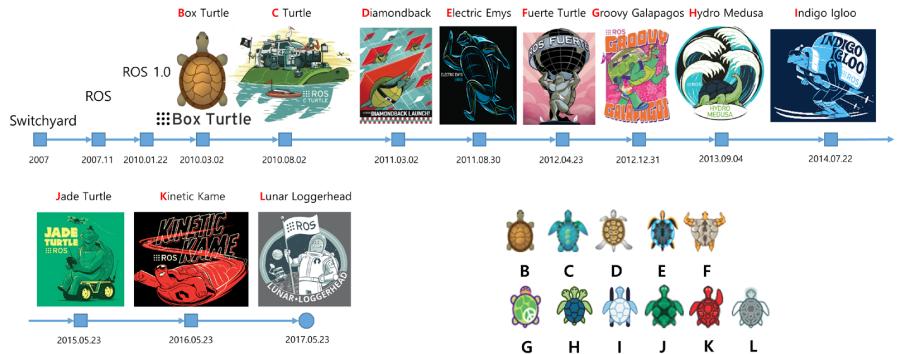


FIGURE 2-7 ROS Versions(<http://wiki.ros.org/>)



FIGURE 2-8 Turtle icons for each version of ROS

Distro	Release Date	Poster	Symbol	EOL Date
Lunar Loggerhead	2017.05.23			2019.05
Kinetic Kame (Recommended)	2016.05.23			2021.04 (Xenial EOL)
Jade Turtle	2015.05.23			2017.05
Indigo Igloo	2014.07.22			2019.04 (Trusty EOL)

FIGURE 2-9 Recent ROS versions and end of support date

Reference Book: ROS Robot Programming (in English). Authors: Yoonseok Pyo, Hancheol Cho, Leon Jung, Darby Lim

ROS (1) Evolution

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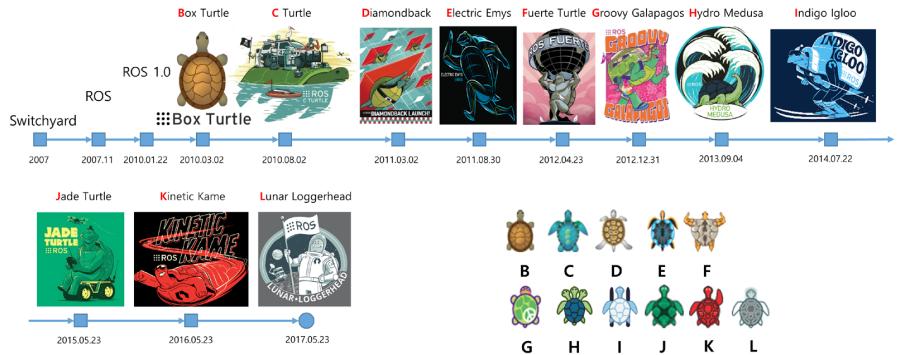


FIGURE 2-7 ROS Versions(<http://wiki.ros.org/>)



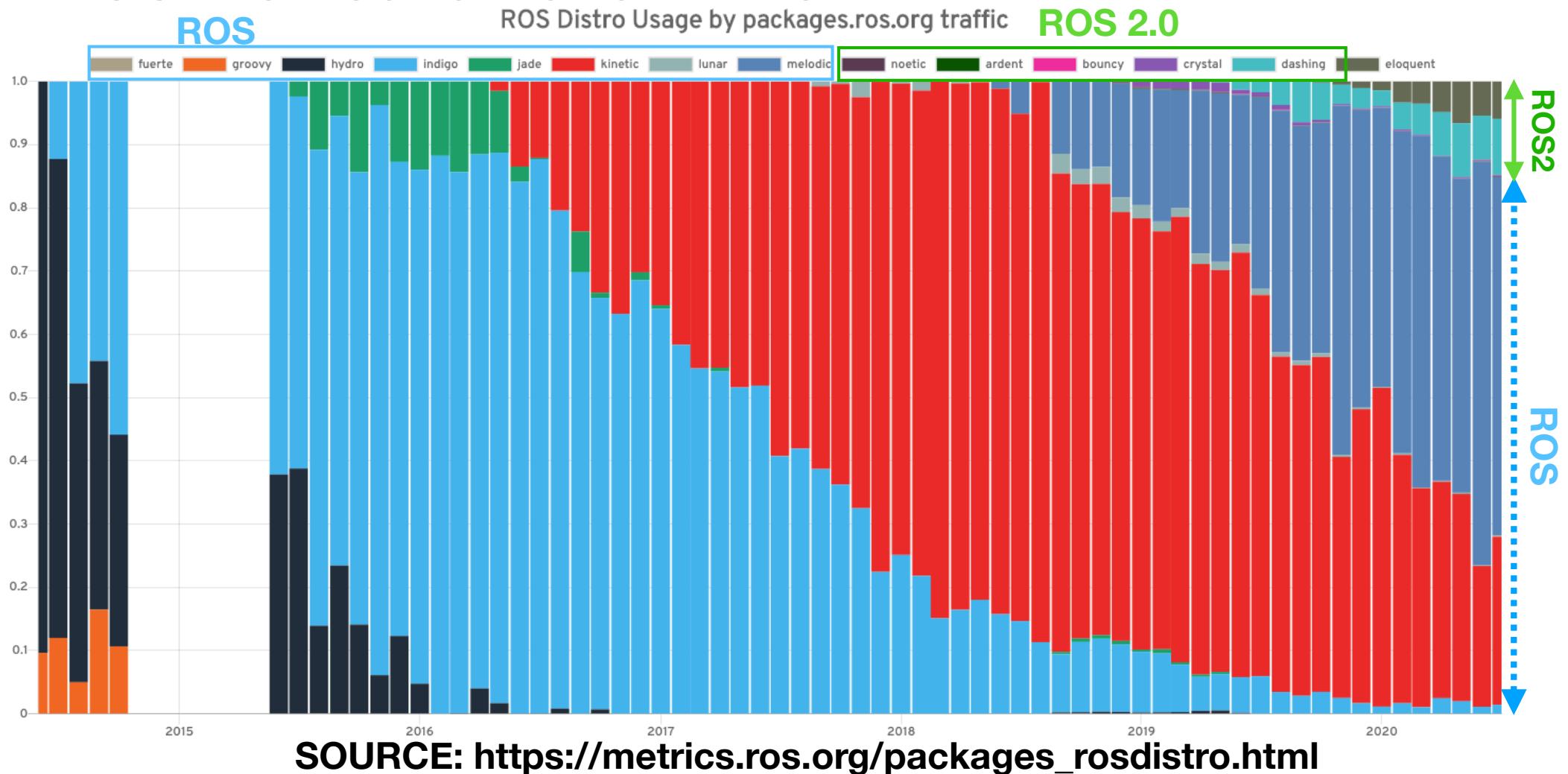
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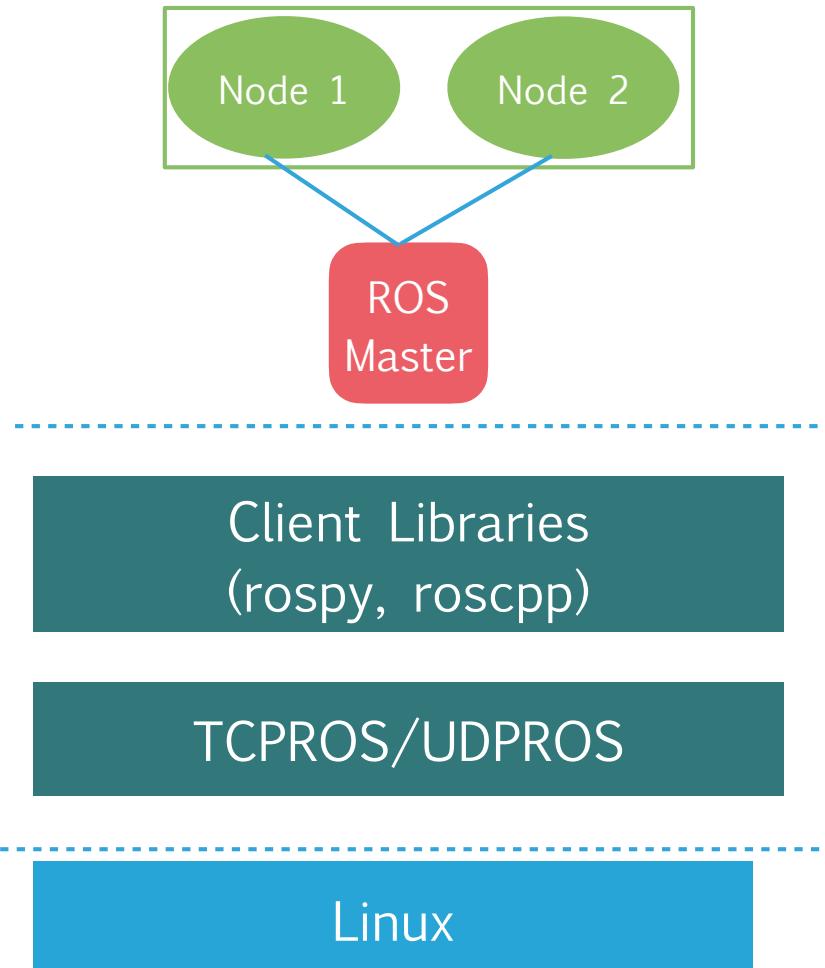
FIGURE 2-9 Recent ROS versions and end of support date

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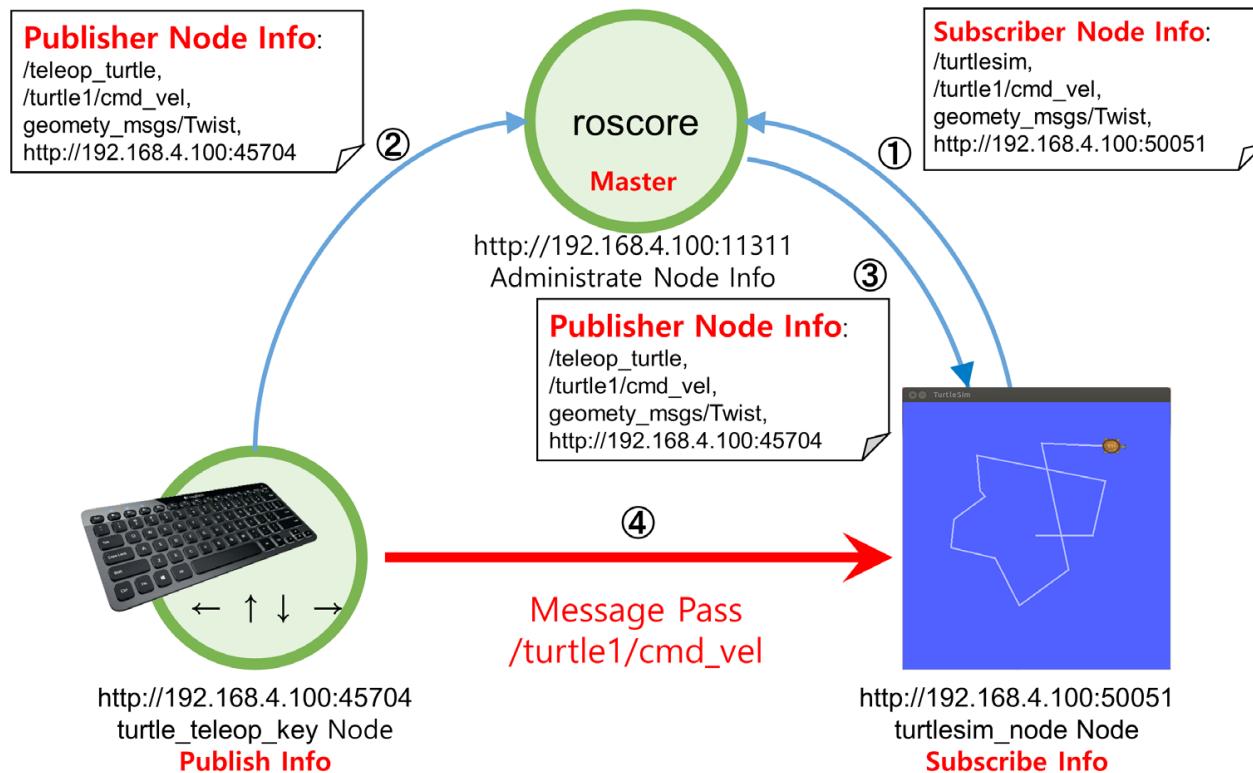
ROS Distribution over Time



ROS Architecture

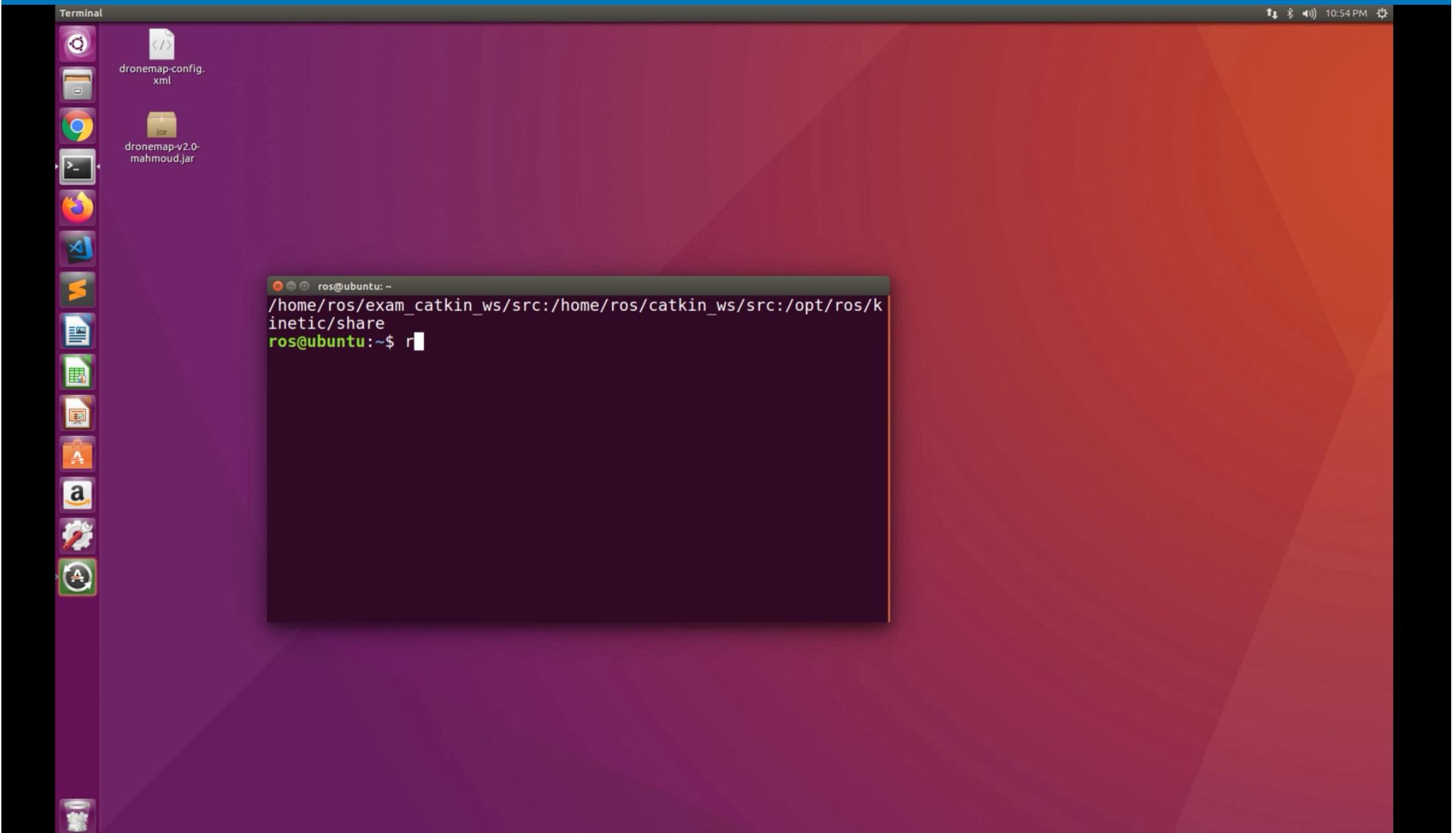


ROS Concepts



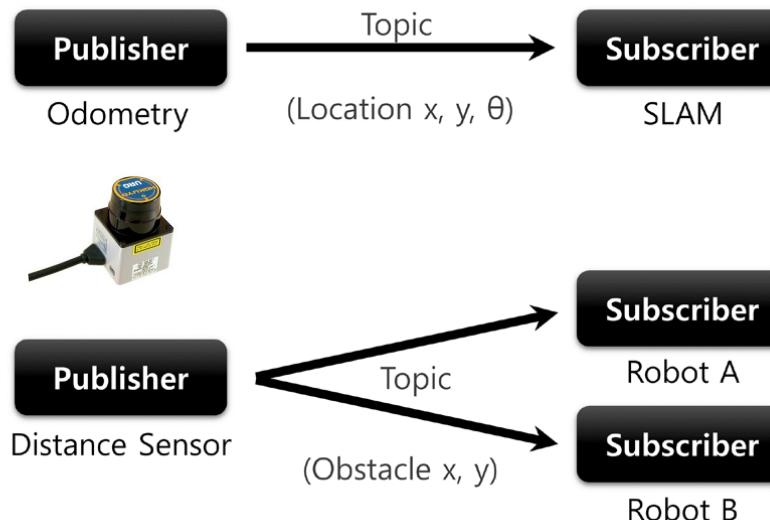
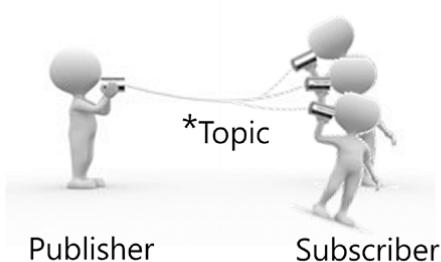
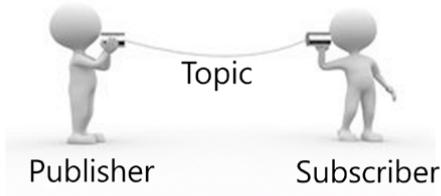
Reference Book: **ROS Robot Programming** (in English).
Authors: Yoonseok Pyo, Hancheol Cho, Leon Jung, Darby Lim

ROBOT OPERATING SYSTEM (ROS) COURSE



Anis Koubaa

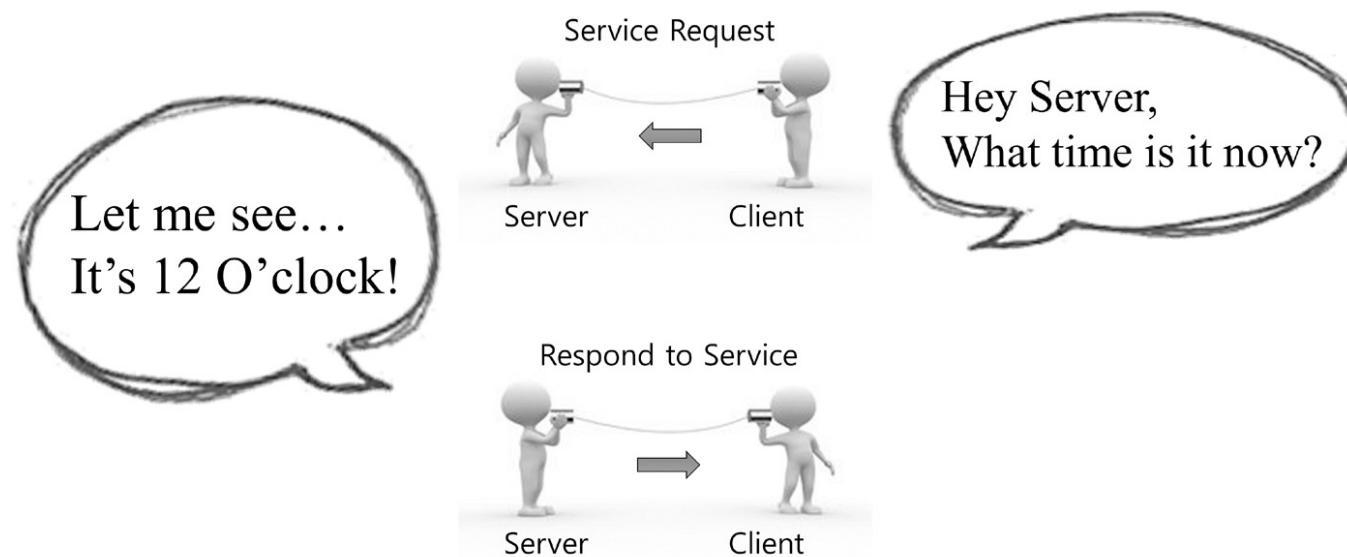
ROS Publisher/Subscriber



*Topic not only allows 1:1 Publisher and Subscriber communication, but also supports 1:N, N:1 and N:N depending on the purpose.

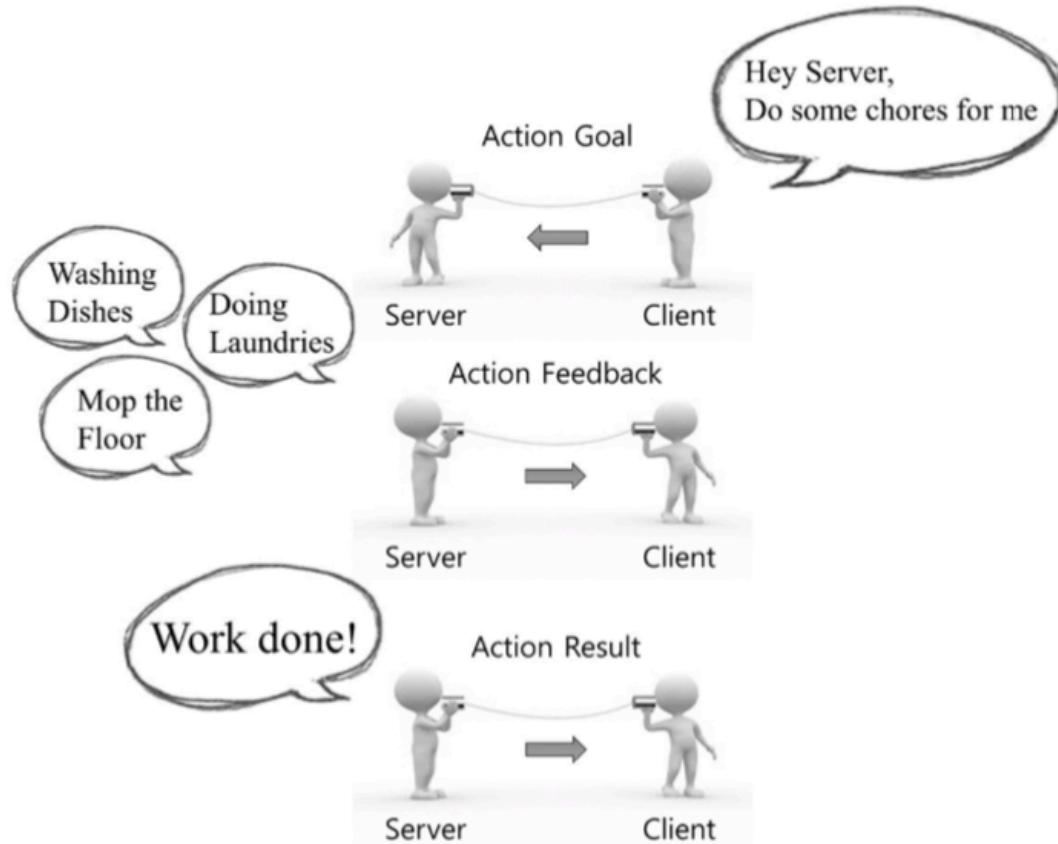
Reference Book: **ROS Robot Programming** (in English).
Authors: Yoonseok Pyo, Hancheol Cho, Leon Jung, Darby Lim

ROS Services



Reference Book: **ROS Robot Programming** (in English).
Authors: Yoonseok Pyo, Hancheol Cho, Leon Jung, Darby Lim

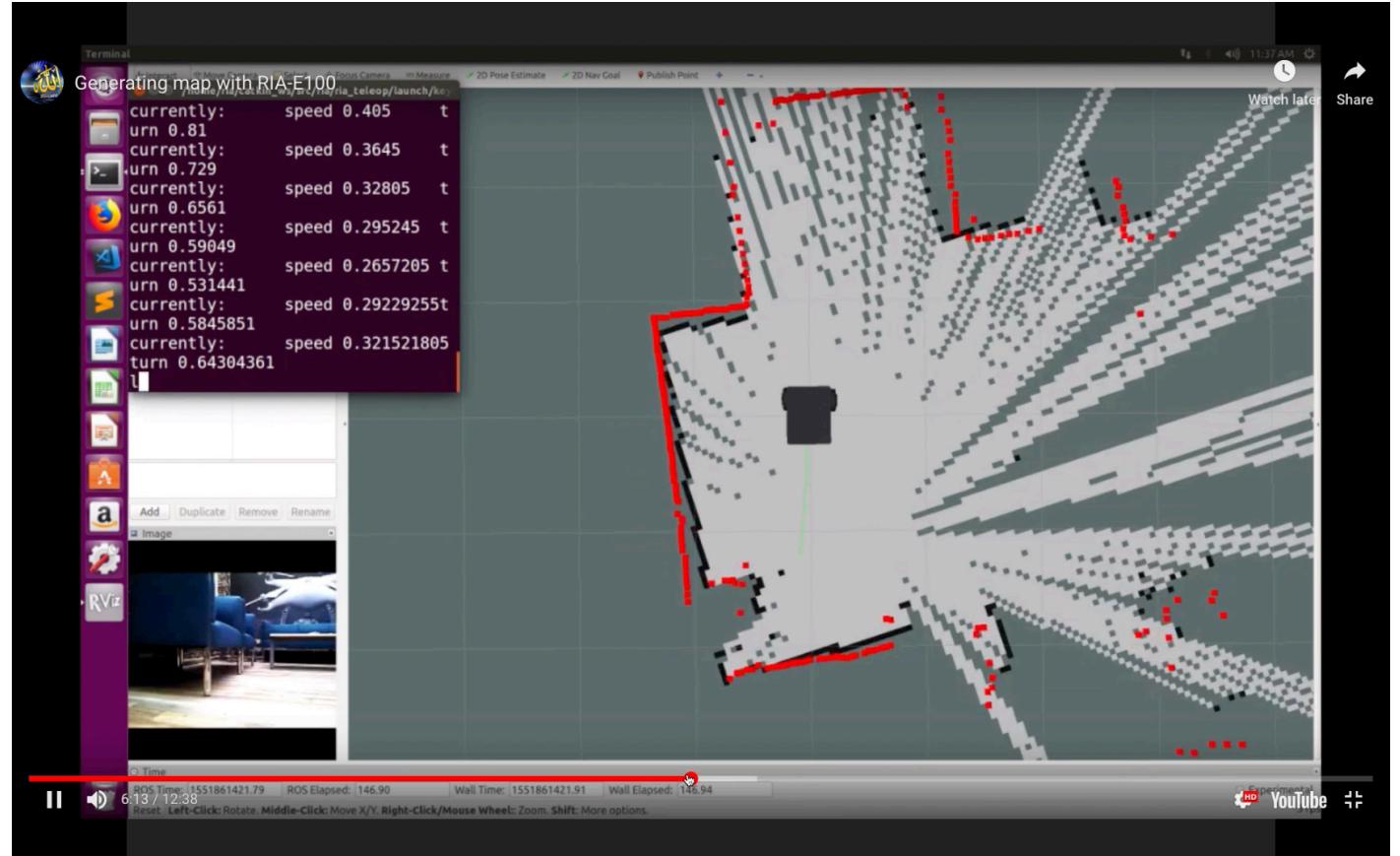
ROS ActionLib



Reference Book: **ROS Robot Programming** (in English).
Authors: Yoonseok Pyo, Hancheol Cho, Leon Jung, Darby Lim

Path Planning

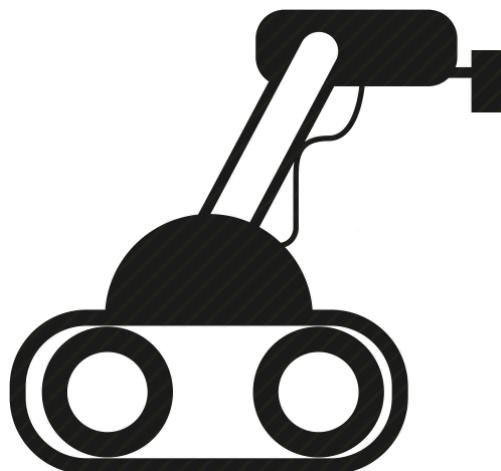
Global Path Planner
Local Path Planner



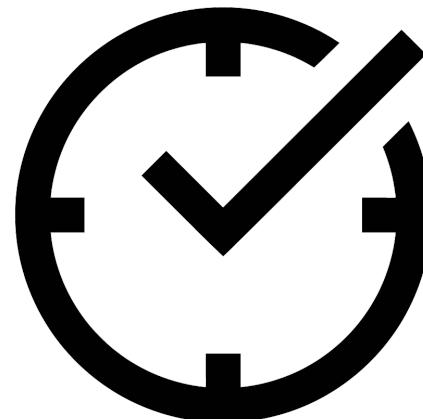


LIMITATIONS OF ROS

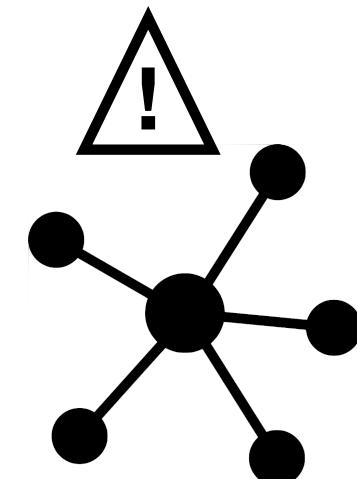
ROS Limitations



Single Robot



Not Real-Time



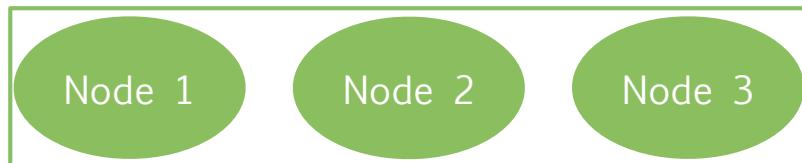
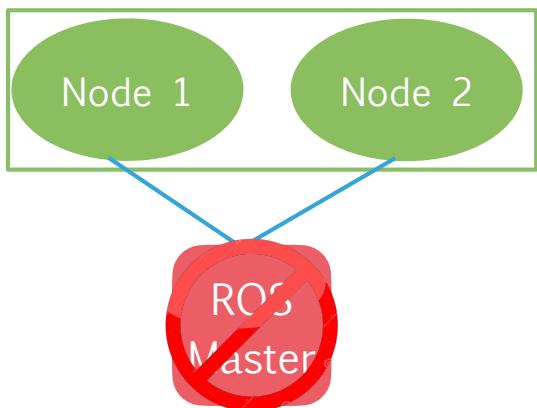
Need Reliable Network

Single Point of Failure

ROS

vs

ROS 2.0



Client Libraries
(rospy, roscpp)

TCPROS/UDPROS

Linux

Client Libraries
(rclpy, rclcpp)

Abstract DDS

DDS

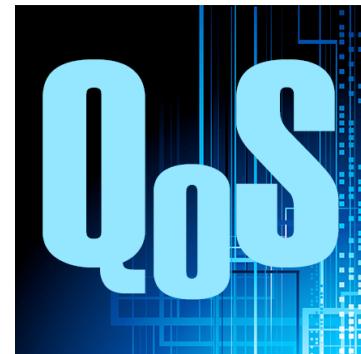
Intra-Process API

Linux/Windows/Mac-OS

ROS2 Use Cases

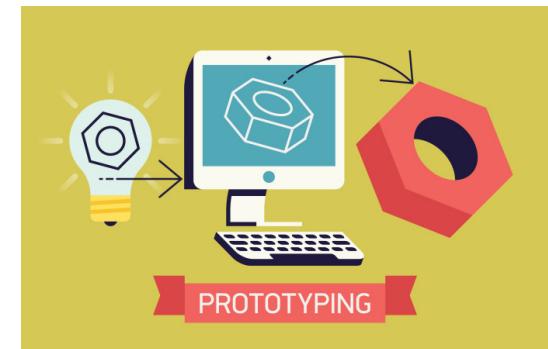
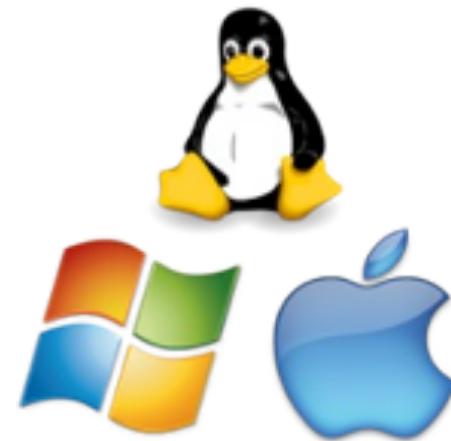


Robotics Swarm



QoS and Real-Time

Cross-Platform



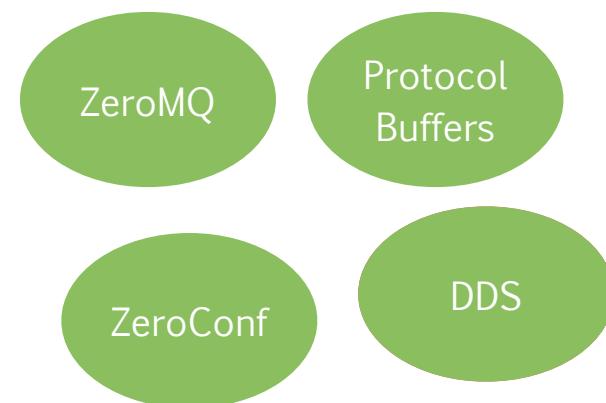
Fast Prototyping
to Production

What Middleware to Choose?

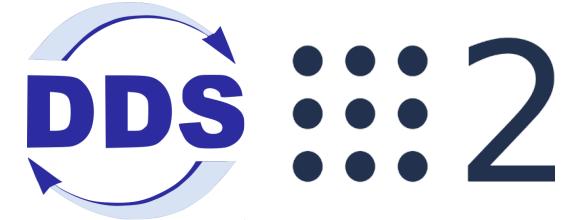
Two options

Improve ROS 1.x Transport

Build new middleware based
on existing solutions



Data Distribution Service



- ▶ An industry-standard communication system
- ▶ Designed by Object Management Group
- ▶ **Data-Centric Publish Subscribe** (DCPS) system
- ▶ Real-time machine-to-machine (middleware) communication
- ▶ Uses publish-subscribe pattern
- ▶ Used in: financial trading, air-traffic control, smart grid management, big data and IoT applications
- ▶ Started in 2001 with two vendors: RTI in the US and Thales group in France

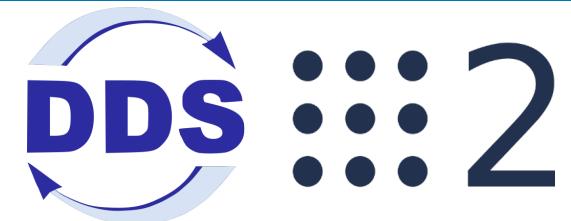
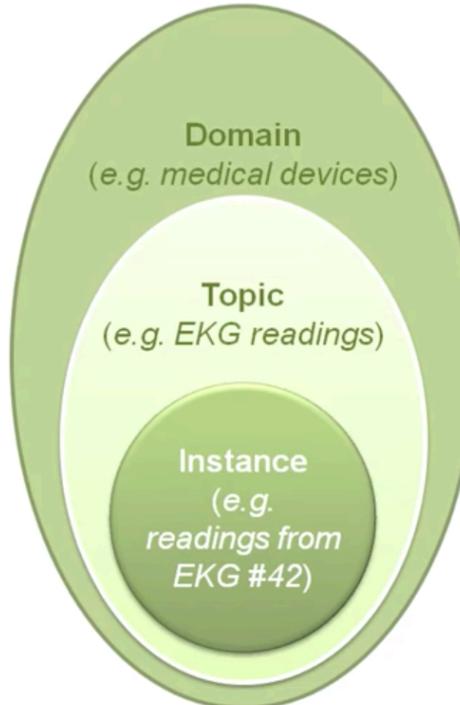
"The DCPS model described in this chapter extends the publish-subscribe model to address the specific needs of real-time, data-critical applications."

Data Distribution Service

How DDS Works: Concepts & Terminology

- **Domain:** world you're talking about
- **Topic:** group of similar things
 - Similar structure ("type")
 - Similar way they change over time ("QoS")} *what how when*
- **Instance:** individual (changing) thing
- **Sample:** snapshot of an instance at a point in time

- **DataWriter:** source of information about part of the world (topic)
- **DataReader:** observer of part of the world (topic)



RTI

DDS in a Nutshell
Data-Centric Architecture and the Data Distribution Service

The Global Leader in DDS Rick Warren, Director of Technical Solutions rick.warren@rti.com

DDS in a Nutshell

17,415 views • Feb 10, 2011

rti Real-Time Innovations
1.07K subscribers

[https://www.youtube.com/
watch?v=u-saogMmKOo](https://www.youtube.com/watch?v=u-saogMmKOo)

2011

Why DDS?

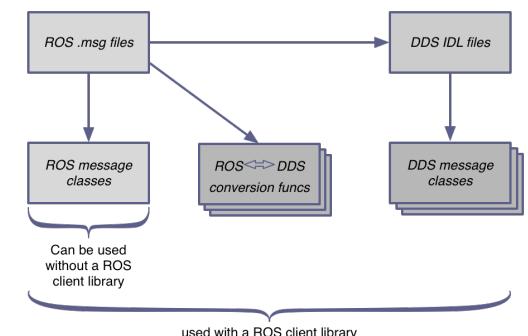
- ▶ DDS is a networking middleware
- ▶ Simplifies complex network programming
- ▶ Implements a publish-subscribe pattern for sending and receiving data, events, and commands among the nodes.
- ▶ Similar to ROS, (publishers) create "topics" (e.g., temperature, location, pressure) and publish "samples"
- ▶ DDS allows the user to specify quality of service (QoS) parameters (QoS Profiles in ROS2)

Discovery

- ▶ DDS replaces the ROS master discovery system
- ▶ DDS API provides information on nodes topics, services, etc.
- ▶ Users are prevented from direct access to DDS (hidden behind ROS APIs)
- ▶ Fully distributed discovery process (no single point of failure)

Message

- ▶ ROS2 maintains the same message definitions as in ROS1
- ▶ ROS 1.x .msg files are converted into .idl files to be used by DDS transport layer
- ▶ Experiments show that cost of message conversion is non significant as compared to cost of serialization.



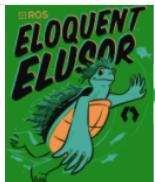
No Vendor Lock

There is currently support for eProsimma FastRTPS, ADLINK's OpenSplice, RTI's Connext DDS and CycloneDDS.



ROS2 Distribution/Learning ROS 2

Logo



Eloquent Elusor

Nov 22nd, 2019



Dashing Diademata

May 31st, 2019



Crystal Clemmys

December 14th, 2018



Bouncy Bolson

July 2nd, 2018



Ardent Apalone

December 8th, 2017



Foxy Fitzroy

June 5th, 2020

<http://emanual.robotis.com/>

The screenshot shows a web browser window with the URL http://emanual.robotis.com/docs/en/platform/turtlebot3/ros2_basic_operation/#ros-2-basic-operation. The page title is "18. [ROS 2] Basic Operation". A sidebar on the left lists topics from 16. [ROS 2] Setup to 25. [ROS 2] Applications. The main content area displays the "18. [ROS 2] Basic Operation" section, which includes a note about placing the robot on a level surface, a "NOTE" section with instructions for Ubuntu 18.04 and ROS Dashing Diademata, and a "Remote PC" section with instructions for running rqt.

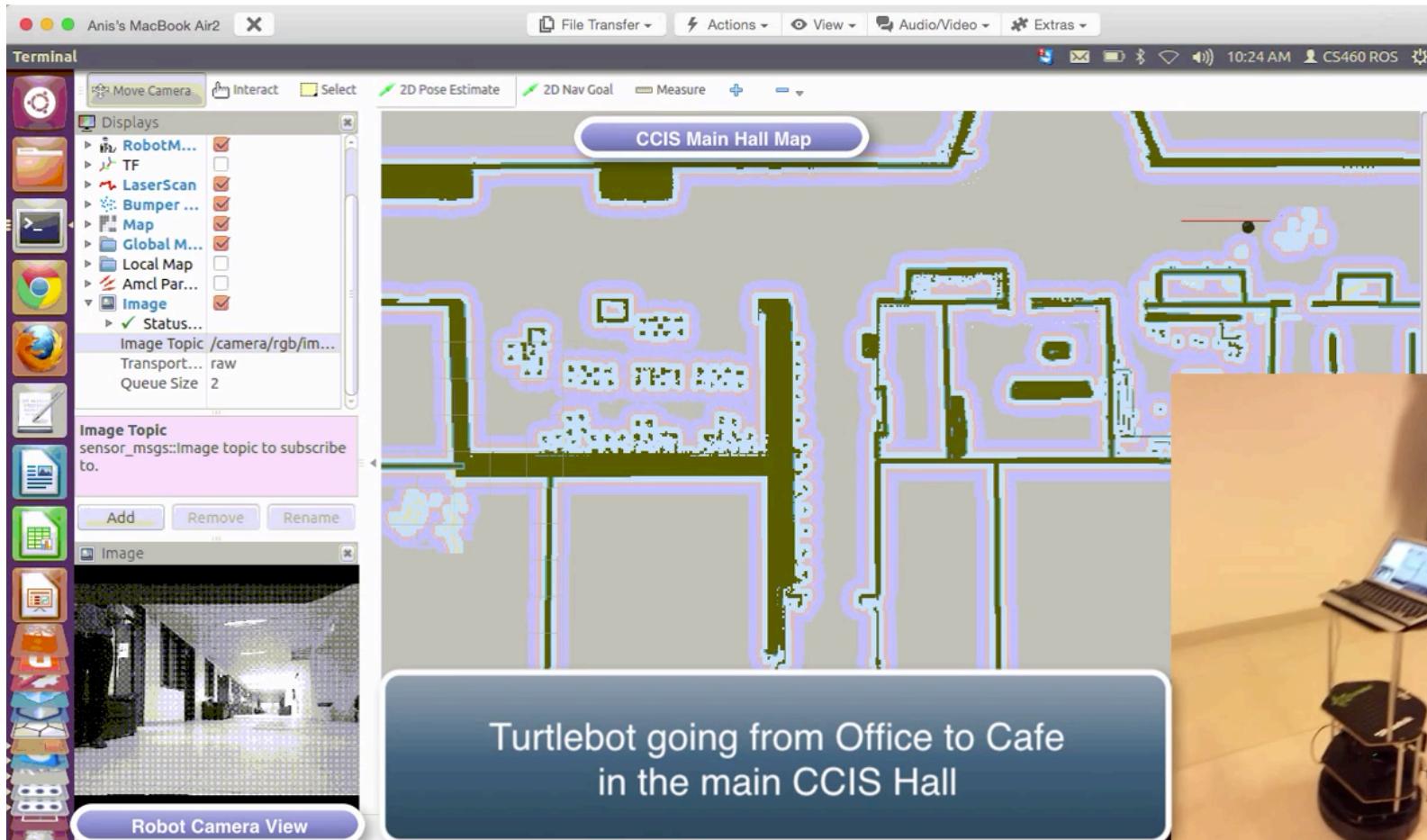


CONTRIBUTIONS TO ROS



CONTRIBUTIONS TO ROS

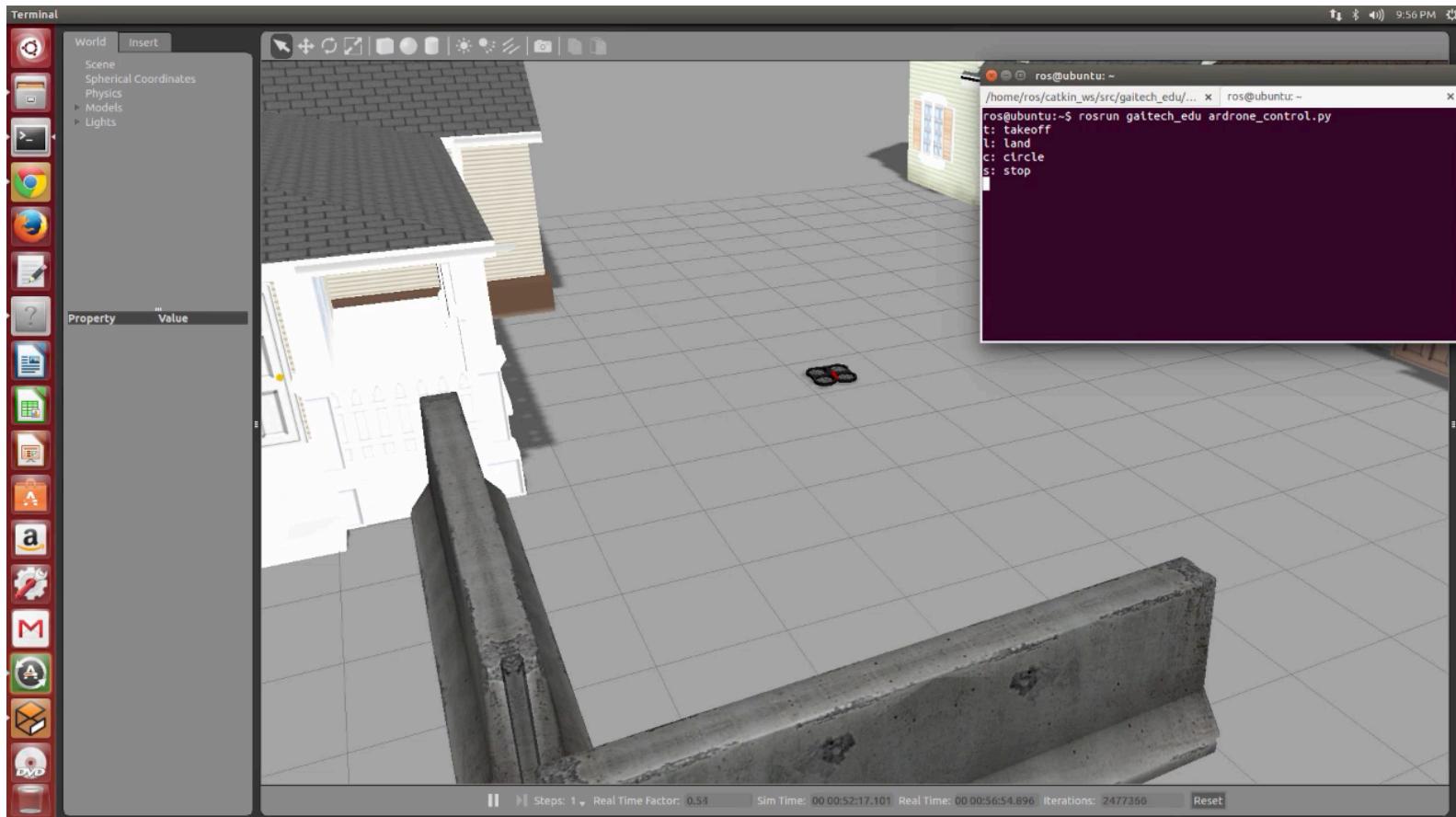
Using ROS in Education



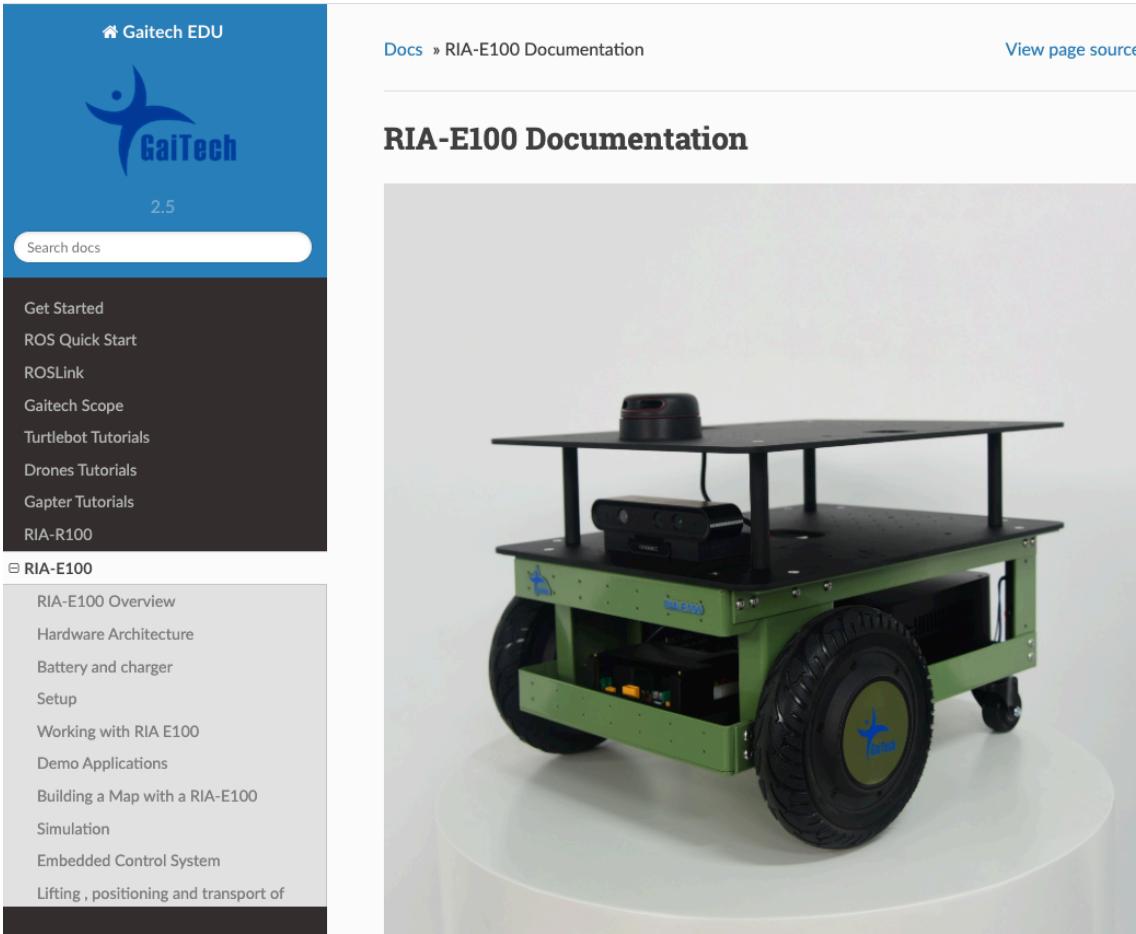
Using ROS in Education



Using ROS in Education



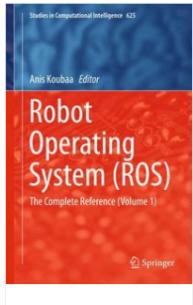
Using ROS in Education



The screenshot shows a documentation page for the RIA-E100 robot. At the top left is the Gaitech logo and a search bar. The top right has links for "Docs" (which is active), "RIA-E100 Documentation", and "View page source". The main title is "RIA-E100 Documentation". Below the title is a large image of a green RIA-E100 mobile robot with a black top plate and a camera mounted on top. The left sidebar contains a navigation menu with sections like "Get Started", "ROS Quick Start", "ROSLink", "Gaitech Scope", "Turtlebot Tutorials", "Drones Tutorials", "Gapter Tutorials", "RIA-R100", and "RIA-E100". Under "RIA-E100", there are sub-links for "RIA-E100 Overview", "Hardware Architecture", "Battery and charger", "Setup", "Working with RIA E100", "Demo Applications", "Building a Map with a RIA-E100", "Simulation", "Embedded Control System", and "Lifting , positioning and transport of".

<http://edu.gaitech.hk/>

Springer Books



BOOK

Robot Operating System (ROS) - 2016

The Complete Reference (Volume 1)

Editors: Anis Koubaa

The objective of this book is to provide the reader with a comprehensive coverage on the Robot Operating Systems (ROS) and latest related systems, which is currently considered as the main development framework for robotics applications.

[Read more](#)

Downloads

212K

Citations

99

Reviews

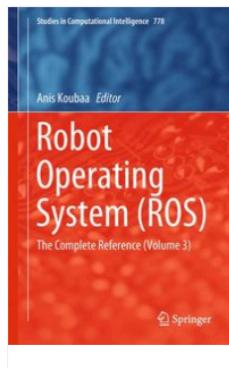
1

Mentions

8

Readers

328



BOOK

Robot Operating System (ROS) - 2019

The Complete Reference (Volume 3)

Editors: Dr. Anis Koubaa

Building on the successful first and second volumes, this book is the third volume of the Springer book on the Robot Operating System (ROS): The Complete Reference. The Robot Operating System is evolving from year to year with a wealth of new

[Read more](#)

Downloads

22.8K

Citations

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Reviews

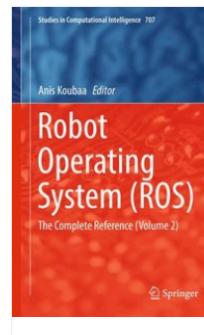
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Mentions

0

Readers

173



BOOK

Robot Operating System (ROS) - 2017

The Complete Reference (Volume 2)

Editors: Anis Koubaa

This second volume is a continuation of the successful first volume of this Springer book, and as well as addressing broader topics it puts a particular focus on unmanned aerial vehicles (UAVs) with Robot Operating System (ROS). Consisting of

[Read more](#)

Downloads

90.5K

Citations

45

Reviews

0

Mentions

0

Readers

211

ROBOTICS AND INTERNET OF THINGS UNIT



Springer Book
Robot Operating System (ROS)
The Complete Reference (Volume 6)

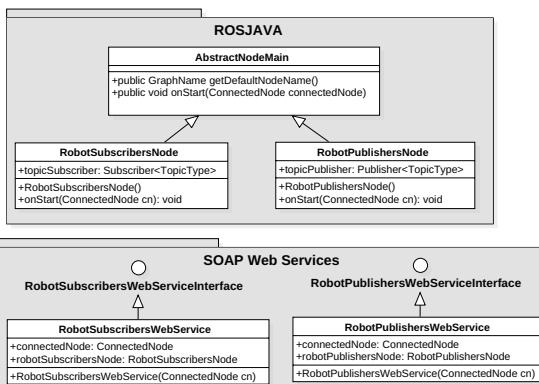
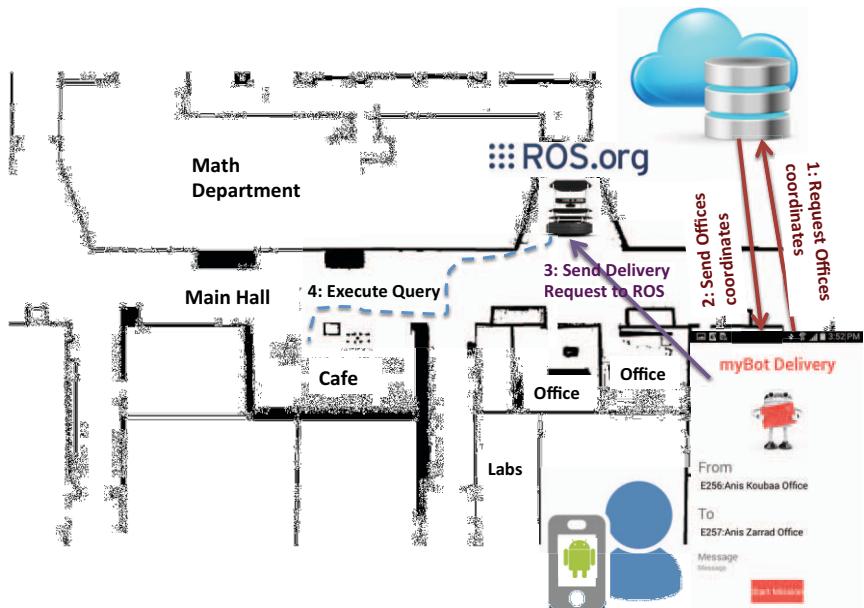
SUBMISSION OPEN

<https://www.riotu-lab.org/rosbook/>

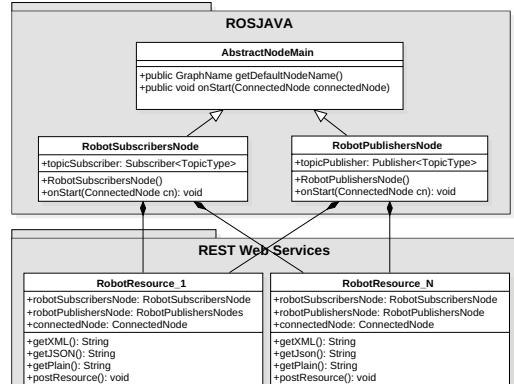
Anis Koubaa

 Robotics &
Internet-of-Things

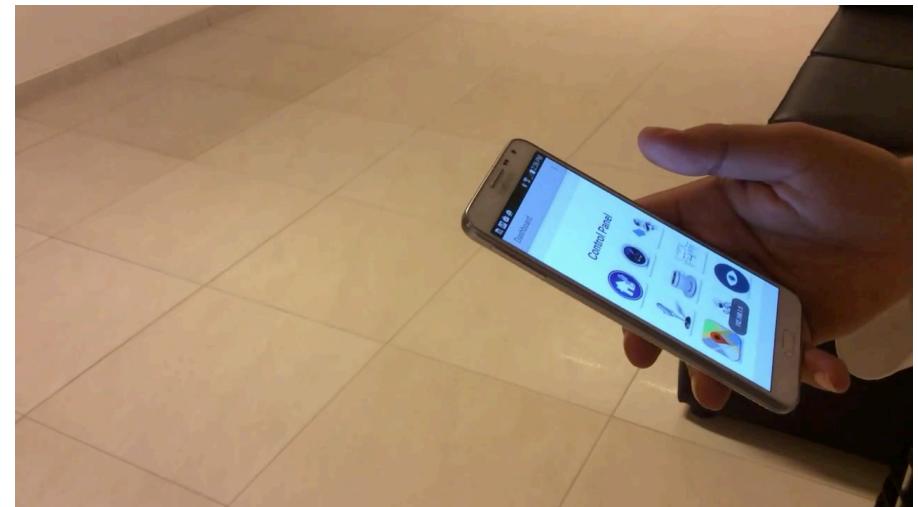
Service Robot



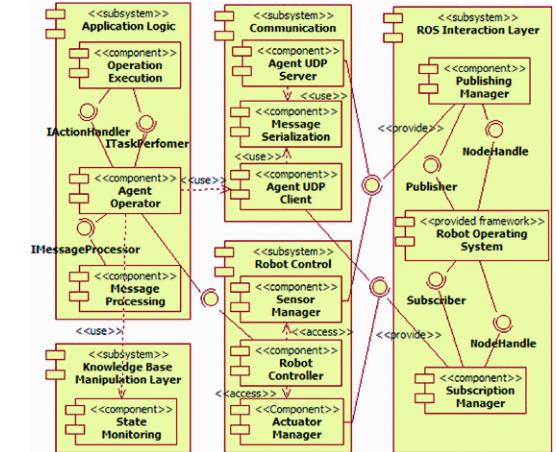
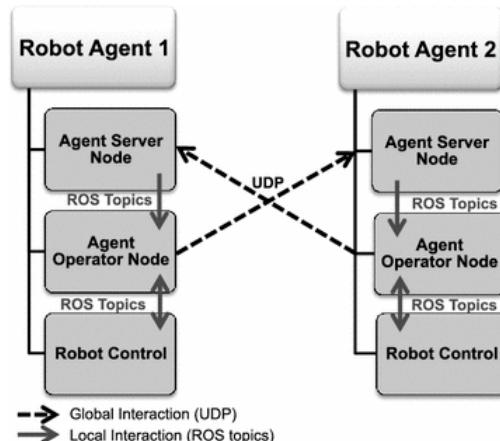
ROSJAVA-SOAP API



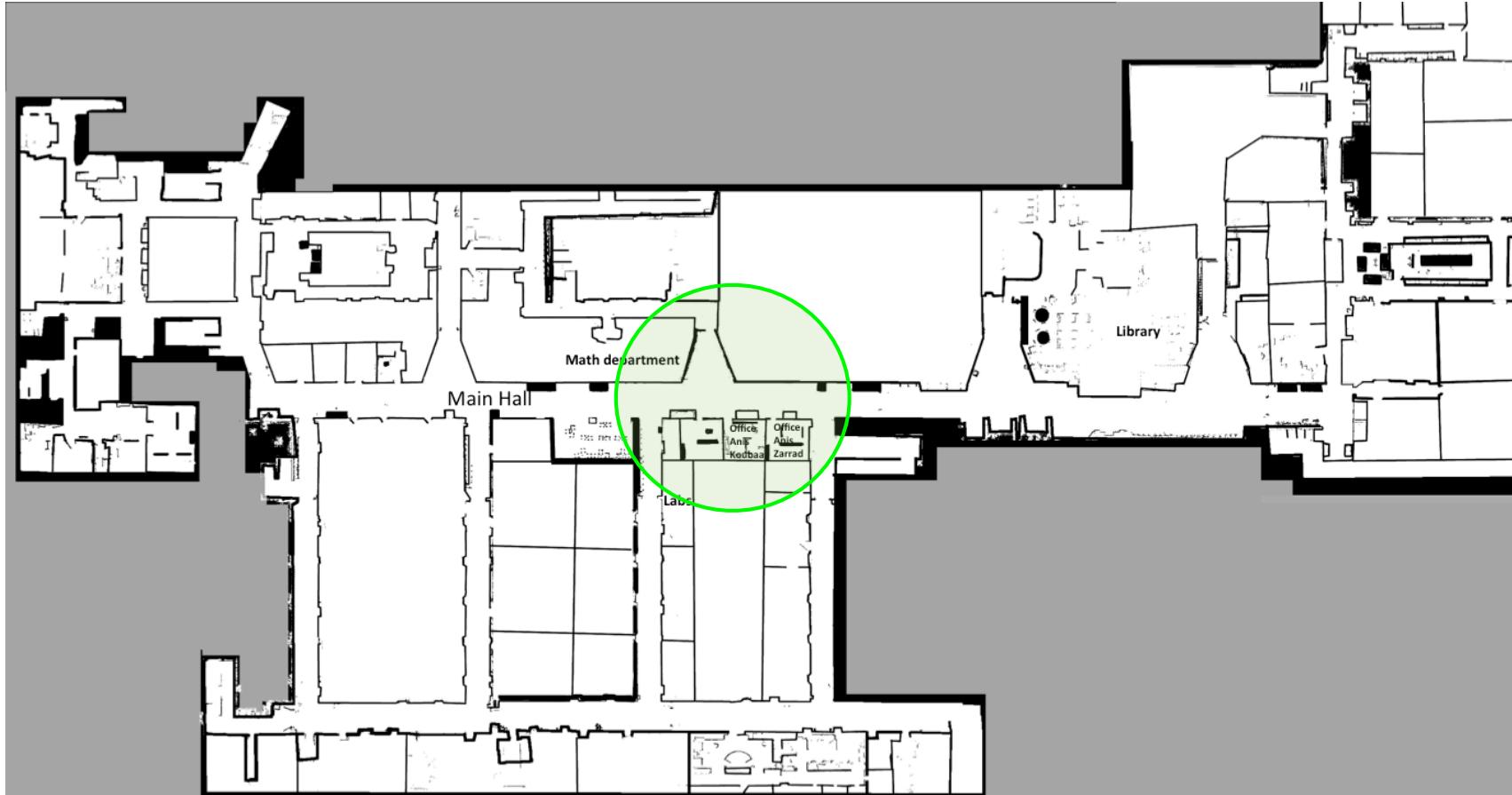
ROSJAVA-REST API



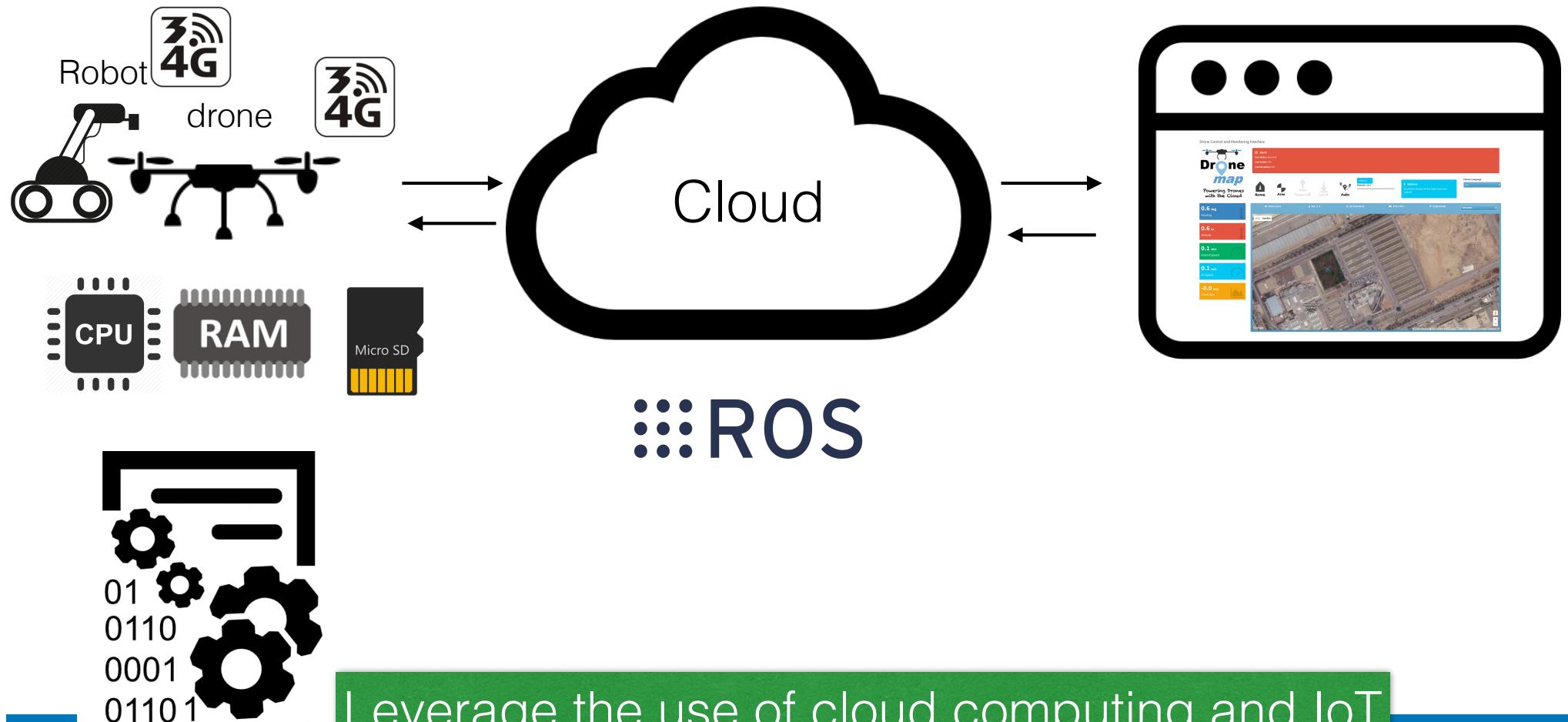
COROS: Multi-Robot Collaboration



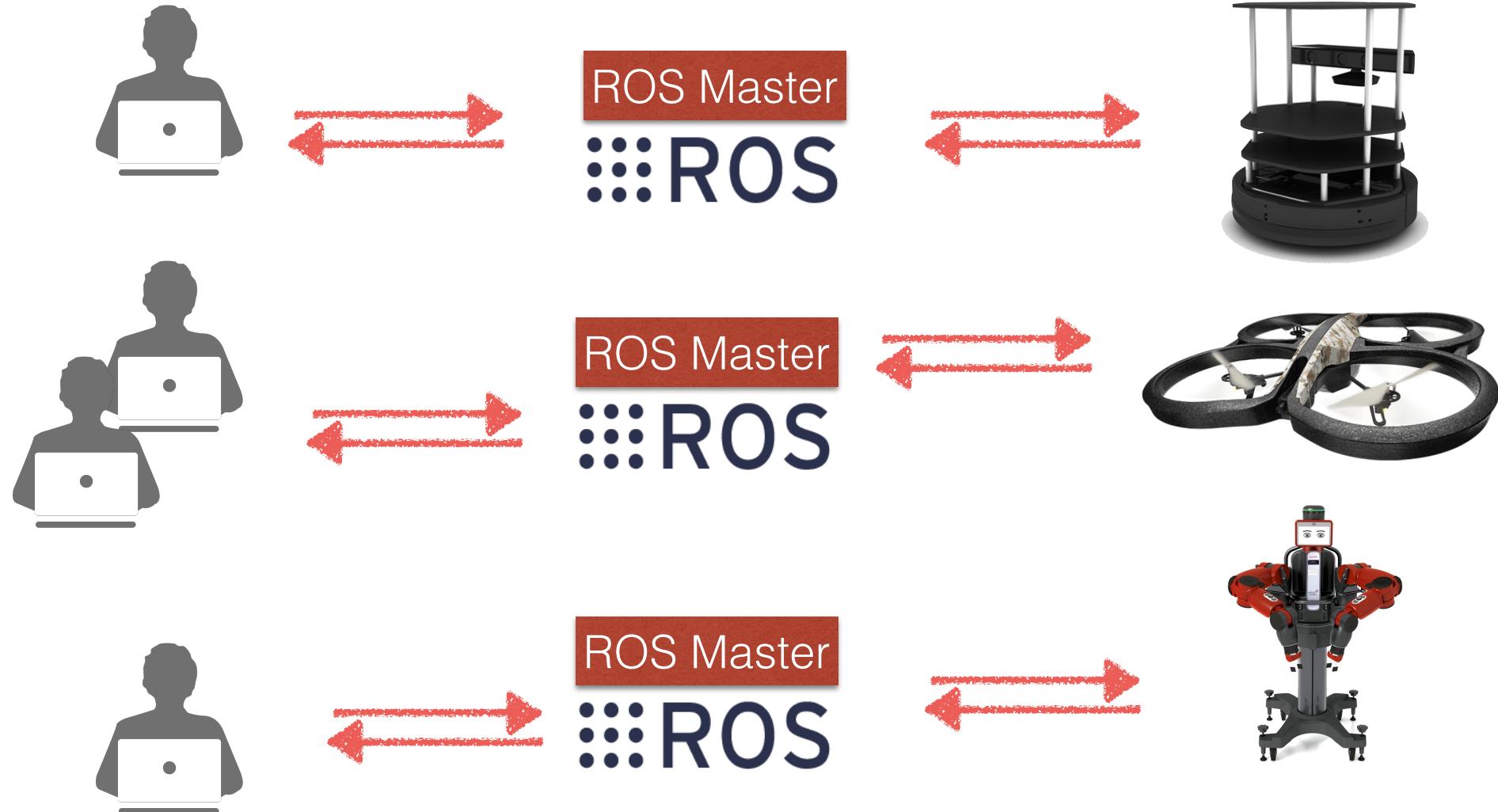
Range Limitation of WLAN



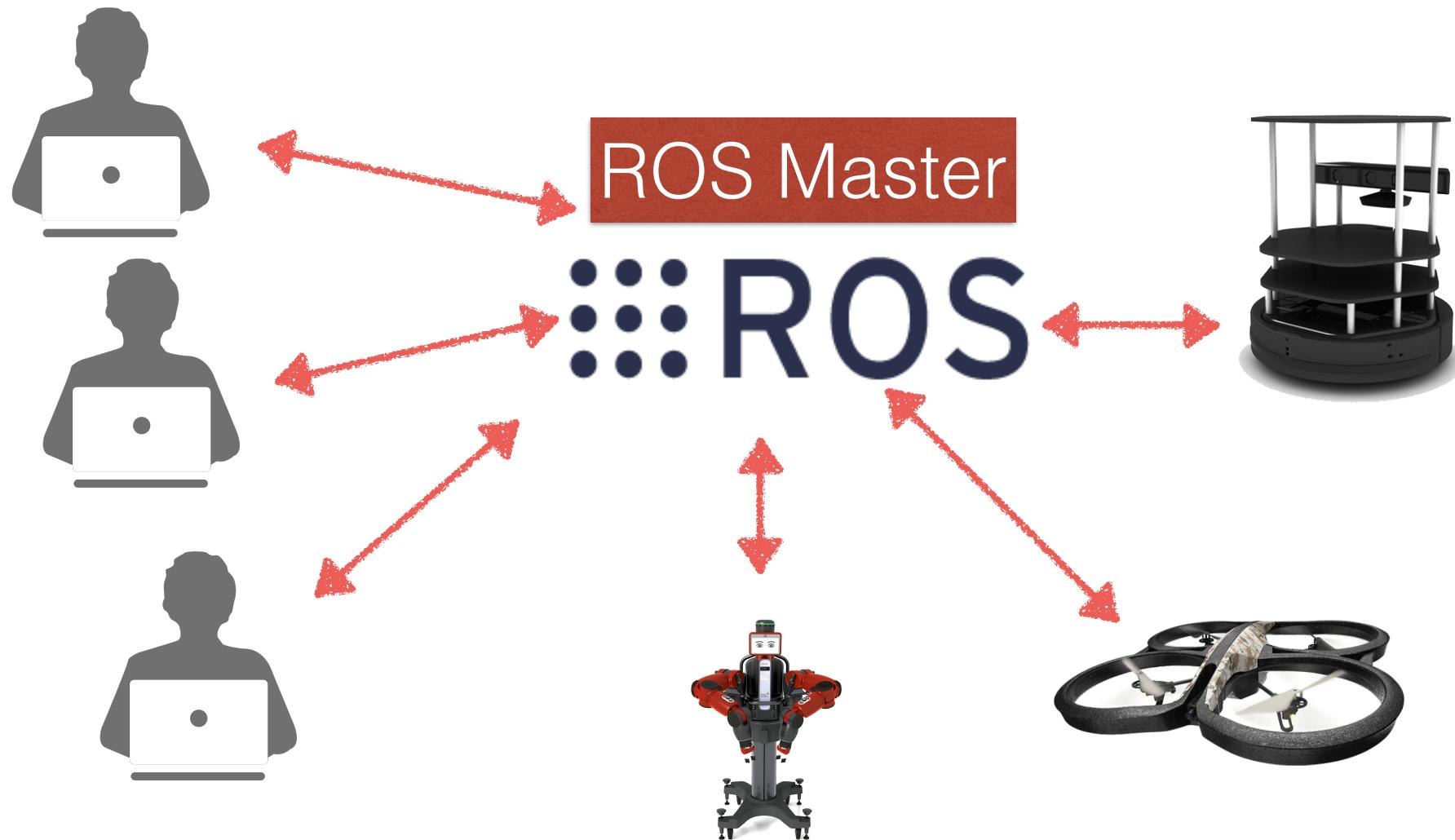
Moving ROS to the Cloud



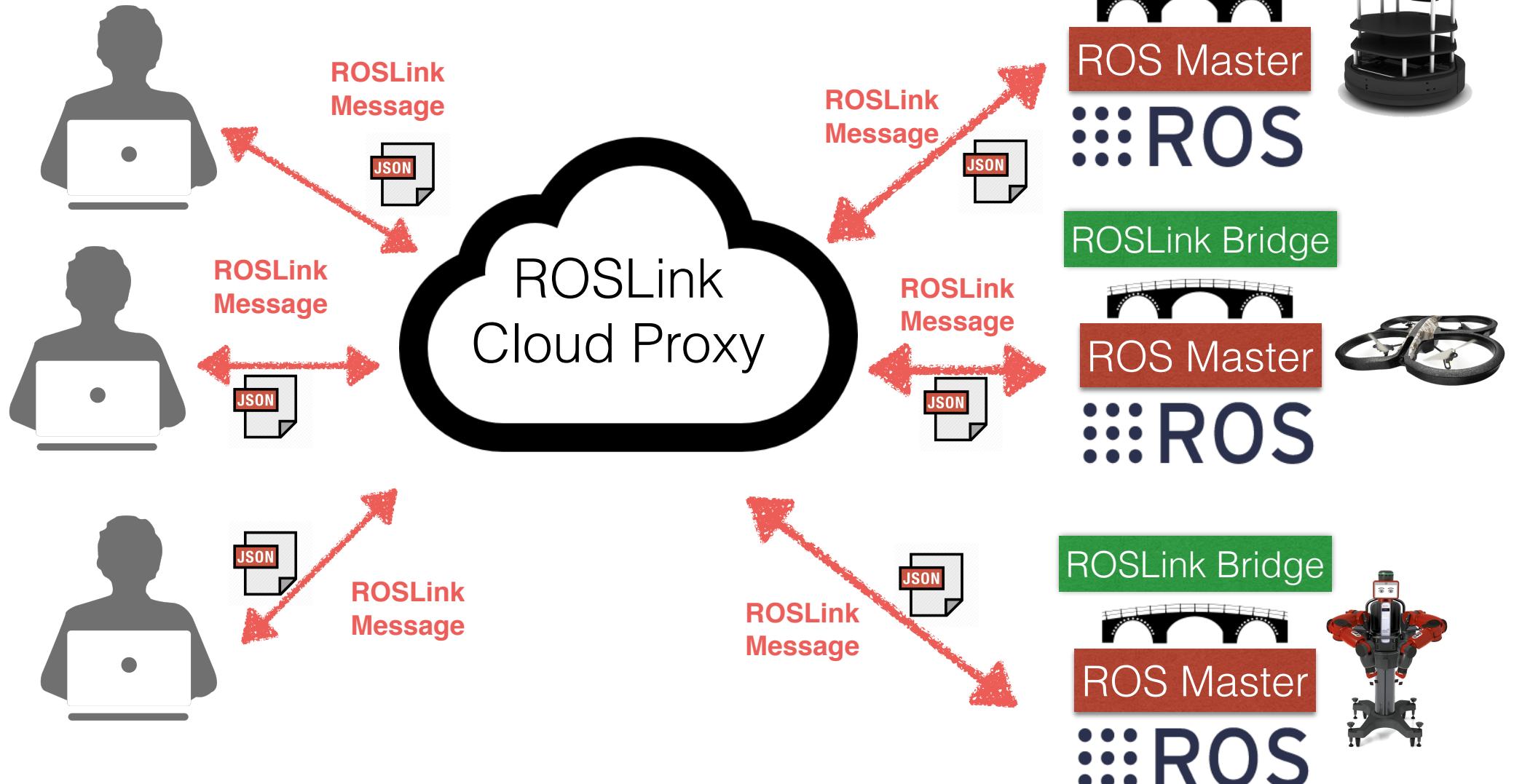
The Single Robot Problem



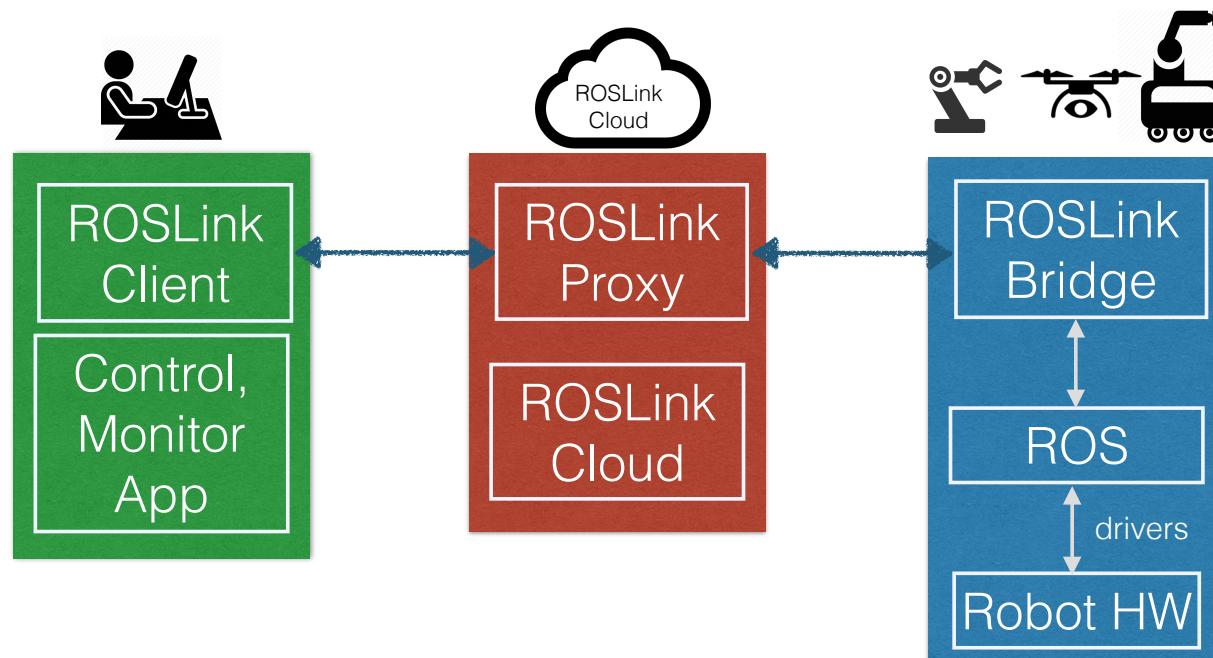
Scalability issue with ROS Master



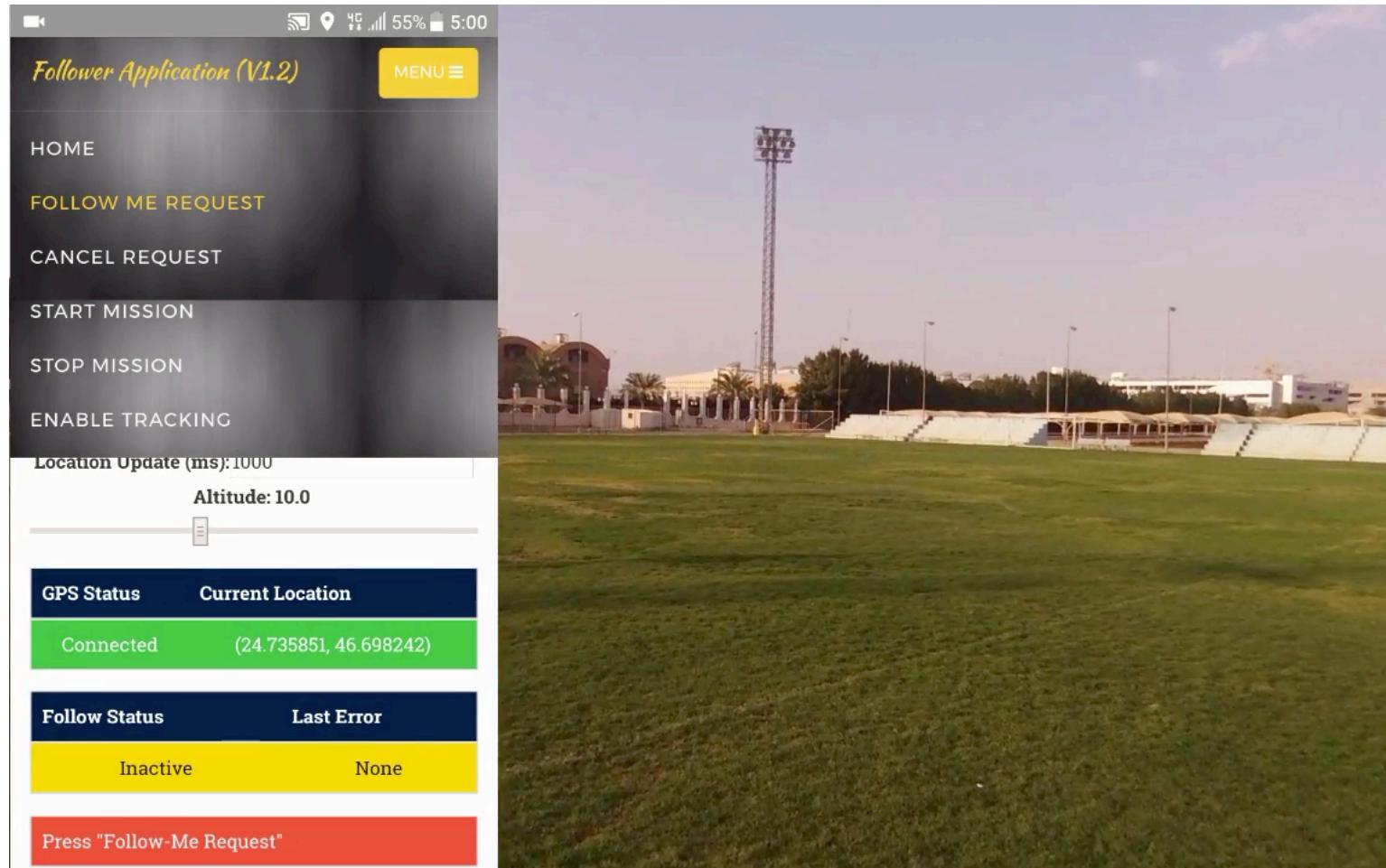
ROSLink Architecture



ROSLink



Controlling a drone over the Internet



5G Robot Teleop using ROS



Platooning using ROS

