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Integrating ROS and ROS2 on mixed-critical robotic systems based on embedded heterogeneous platforms

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Background

Our business units

UTC Aerospace Systems

United Technologies
Climate | Controls | Security

Pratt & Whitney
A United Technologies Company

Otis
A United Technologies Company

United Technologies

is a multinational company
operating in different domains
(aerospace, building systems, aircraft engines, …)

United Technologies Research Center (UTRC) ensures UTC's technological advantage in the market and solve the toughest scientific challenges for our business unit customers

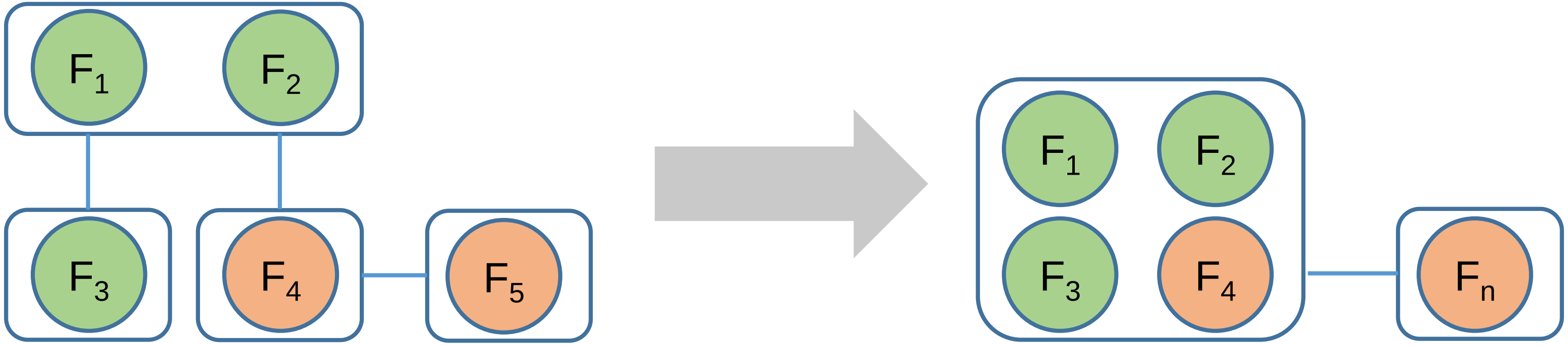
*UTC is not a robot manufacturer, but is a **user & integrator** of robotic and intelligent systems*
Main applications are advanced manufacturing, assembly, manipulation, inspection, …

Proposal

Robotic systems includes **different functions** with a different level of **criticality.** Functions with different criticality are usually allocated on **separate processing units**.

Goal: integration of multiple functions over single, advanced processing units

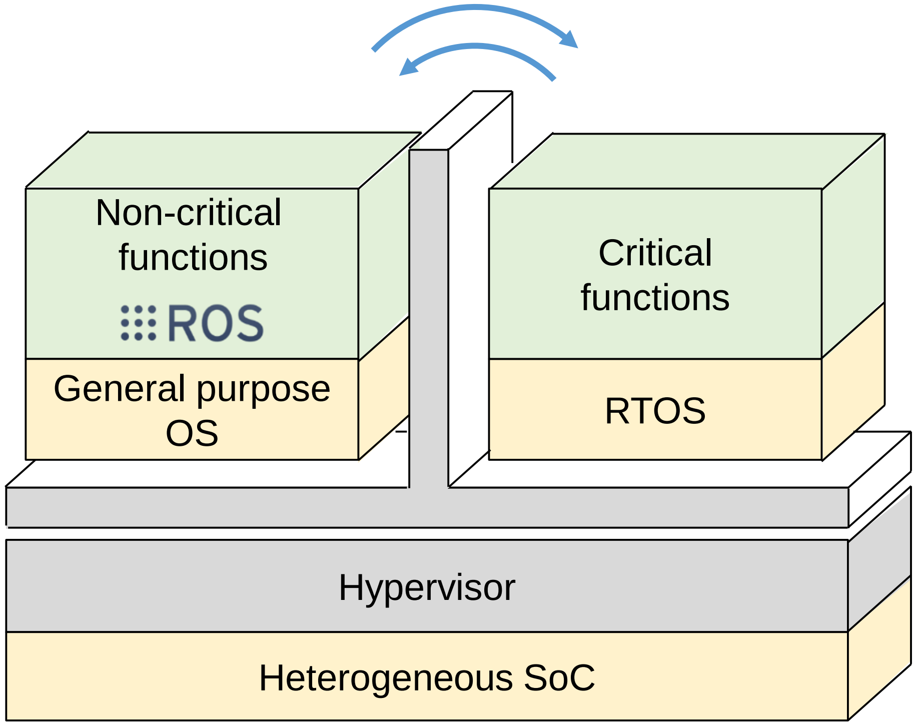
Pros: reduced size, weight, power, cost
Cons: interference



Non mixed-critical scenario

Mixed-critical system

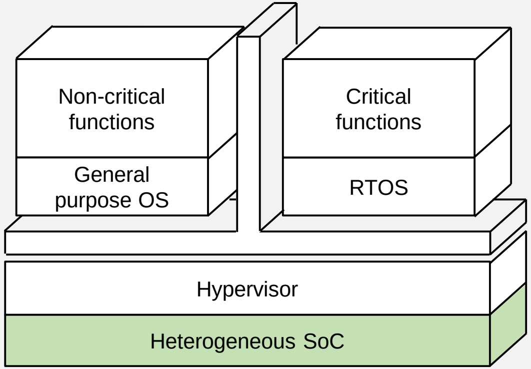
Solution



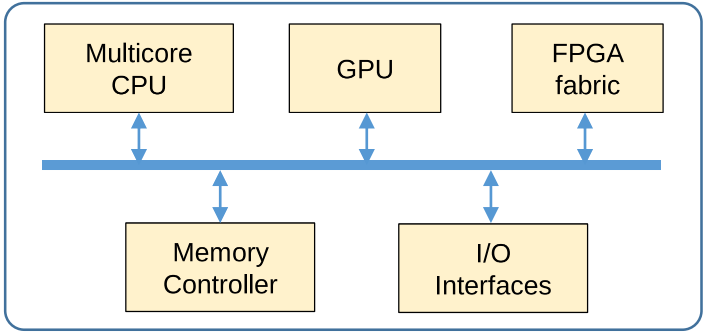
Integration of ROS-based and non-ROS-based application on the same hardware platform

- **Isolation** between different functions (time and space partitioning)
- **Communication** between the different isolated application domains.

Hardware Platforms



COTS heterogeneous devices



Example/Candidates

Nvidia Jetson TX2

Xilinx Zynq Ultrascale+

PROS	- Better **SWaP**, lower-cost - Short time to market
CONS	- Sophisticated (obfuscated) components - Greater complexity - Resource sharing potentially jeopardizing **safety**

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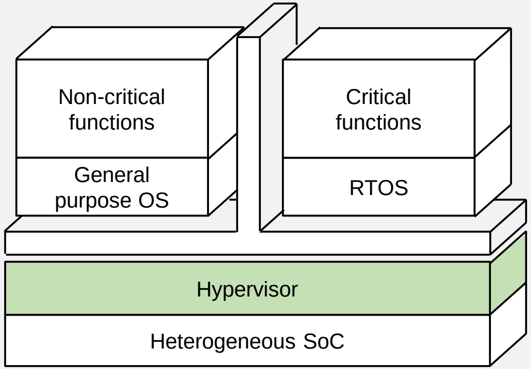
Hypervisor



Jailhouse:

- Partitioning Hypervisor based on Linux.
  - Able to run bare-metal applications or (adapted) operating systems.
- Originally developed by Siemens
- Released as Free Software (GPLv2) since November 2013

https://github.com/siemens/jailhouse

PROS	▪ Native support for the **Linux** kernel ▪ Low latencies, good performance ▪ Open Source (GPL v2) ▪ Ported on several embedded platforms (Xilinx Zynq, Nvidia Jetson TX1/TX2)
CONS	▪ System boot depends on the Linux Kernel ▪ No partition scheduling, only static resource assignment ▪ Limited **maturity**

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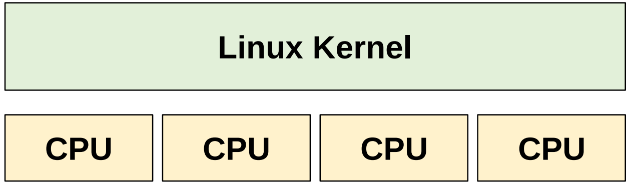
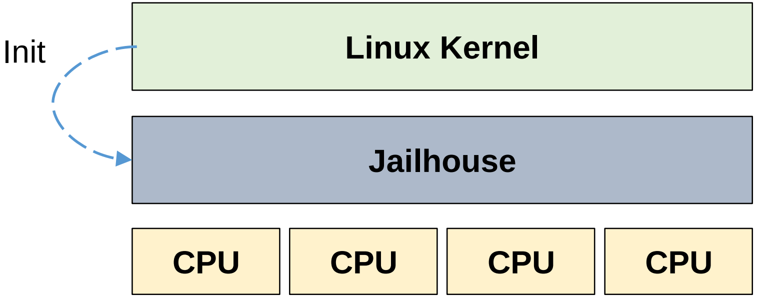
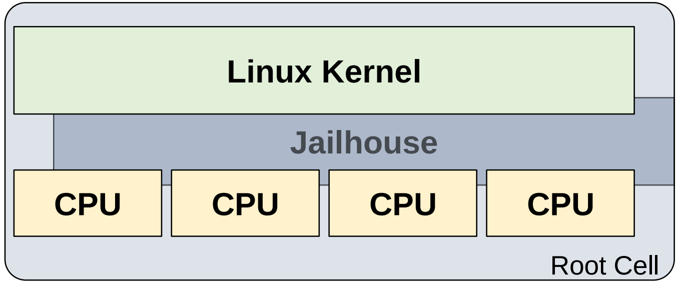
Jailhouse concepts



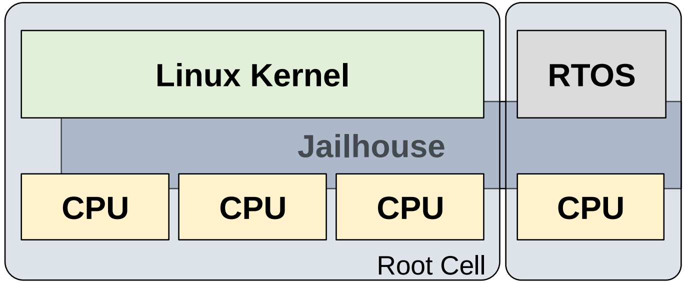
1) Fully booted Linux system



2) Linux loading Jailhouse



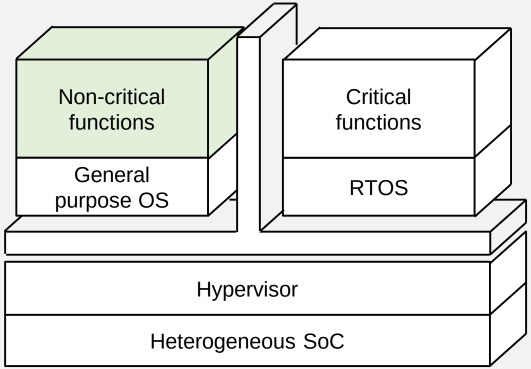
3) Starting the root cell

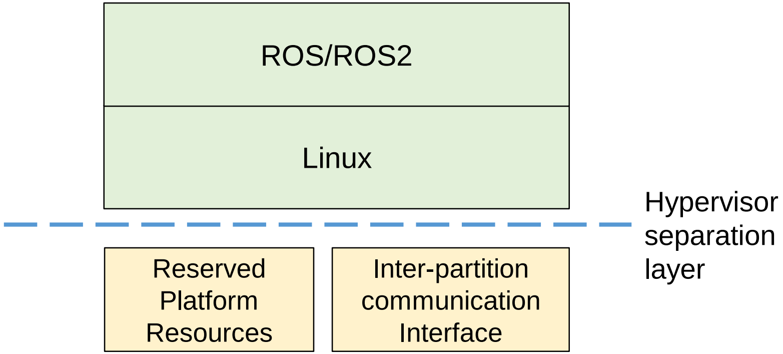


4) Loading an additional cell

R. Ramsauer, J. Kiszka, D. Lohmann, W. Mauerer, «Look Mum, no VM exists! (Almost)», arXiv preprint, arXiv:1705.06932v1

Integrating ROS/ROS 2




ROS/ROS2
Linux
Hypervisor separation layer
Reserved Platform Resources
Inter-partition communication Interface

	ROS	2
PROS	▪ Widely adopted ▪ Large community ▪ Algorithms, Libraries, Drivers	▪ Determinism ▪ Data Distribution Service ▪ Security
CONS	▪ Lack of determinism ▪ Not well fit for safety critical systems	▪ Maturity level ▪ Adoption

Ongoing activity & future work

Ongoing: ROS+Jailhouse benchmarking

- Inter-partition interference
- Hypervisor overhead on performance
- Inter-partition communication

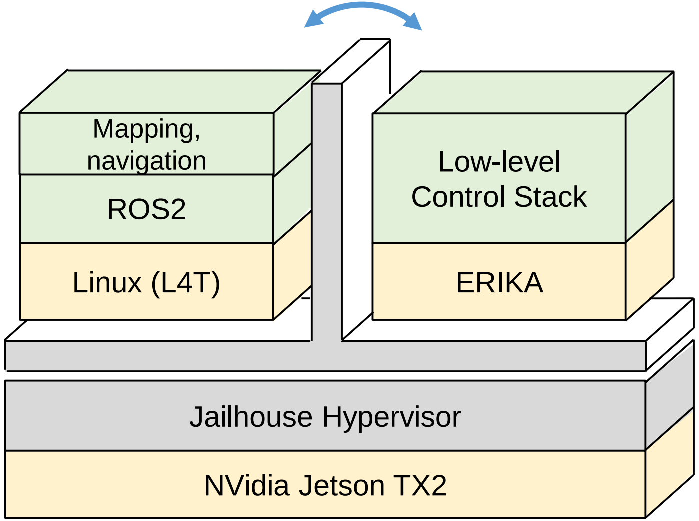
Testing on NVidia Jetson TX2

Communication latency between two nodes in the same partition

	Average Overhead
ROS 1 (Kinetic)	~ +3 %
ROS 2 (Ardent)	~ +5 %

ROS+Linux Vs. ROS+Linux+Jailhouse

Next step: full-stack demonstrator for autonomous UAV



Current collaborations

UNIMORE

HiPeRT Lab

https://hipert.unimore.it

Questions?

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