An Introduction to Asymmetric Multiprocessing: when this architecture can be a game changer and how to survive it.

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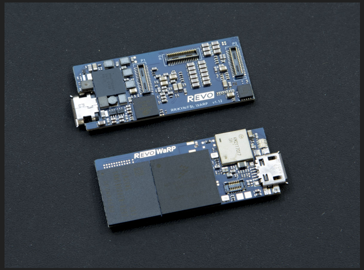
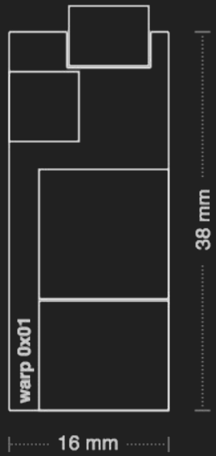
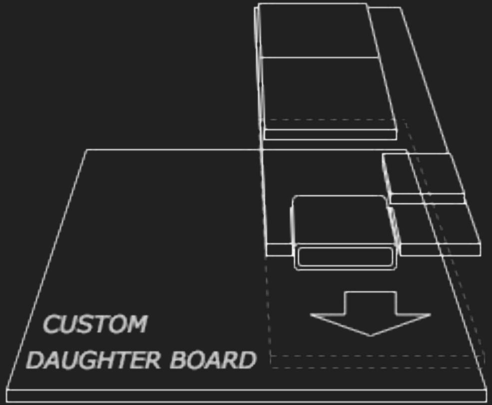
Hybrid Architecture: `warpx.io`

The Hybrid Design Architecture (HDA) combines the power of an application processor with the ease-of-use of micro-controllers.



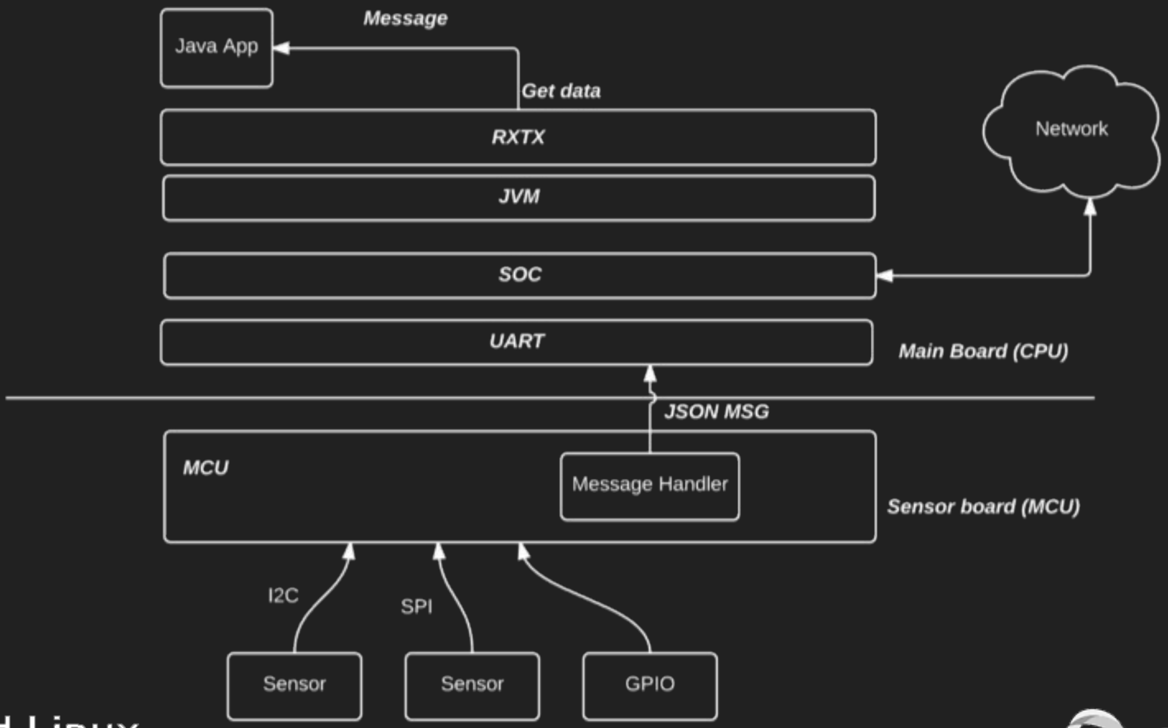




Embedded Linux Conference

OpenIoTSummit

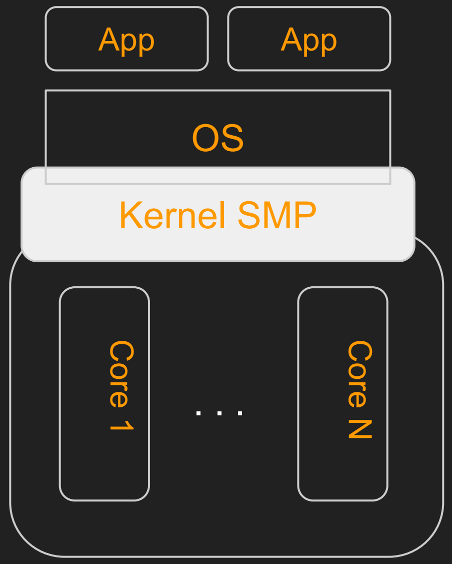
Software on warpx HDA



SMP vs AMP

SMP on homogeneous architectures:

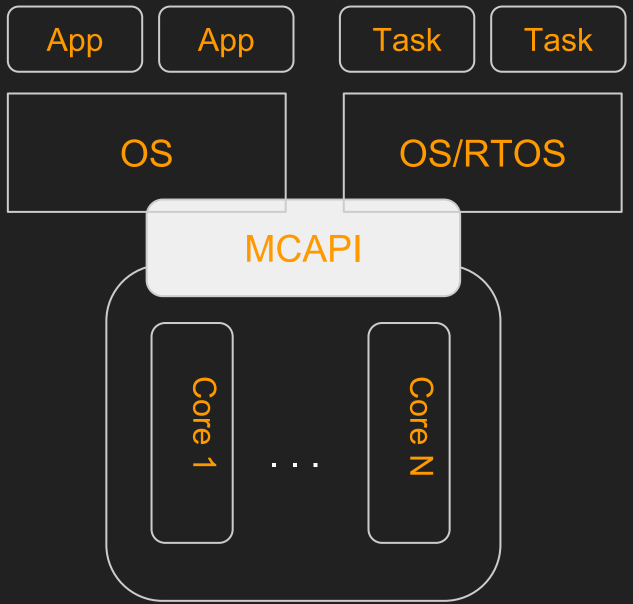
- Single OS controlling two or more identical cores sharing system resources
- Dynamic scheduling and load balancing



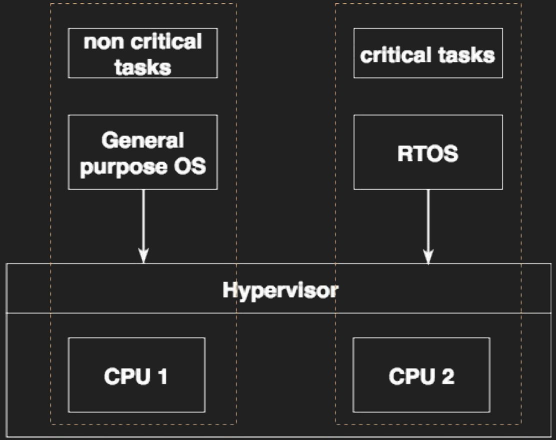
SMP vs AMP

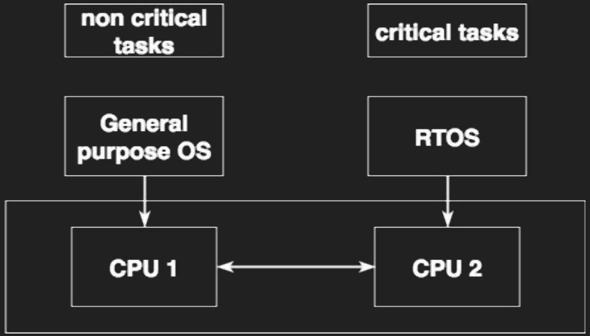
AMP on heterogeneous architectures:

- Different OS on each core --> full-featured OS alongside a real-time kernel
- Inter processor communication protocol
- Efficient when the application can be statically partitioned across cores - high performance is achieved locally



Supervised vs Not Supervised

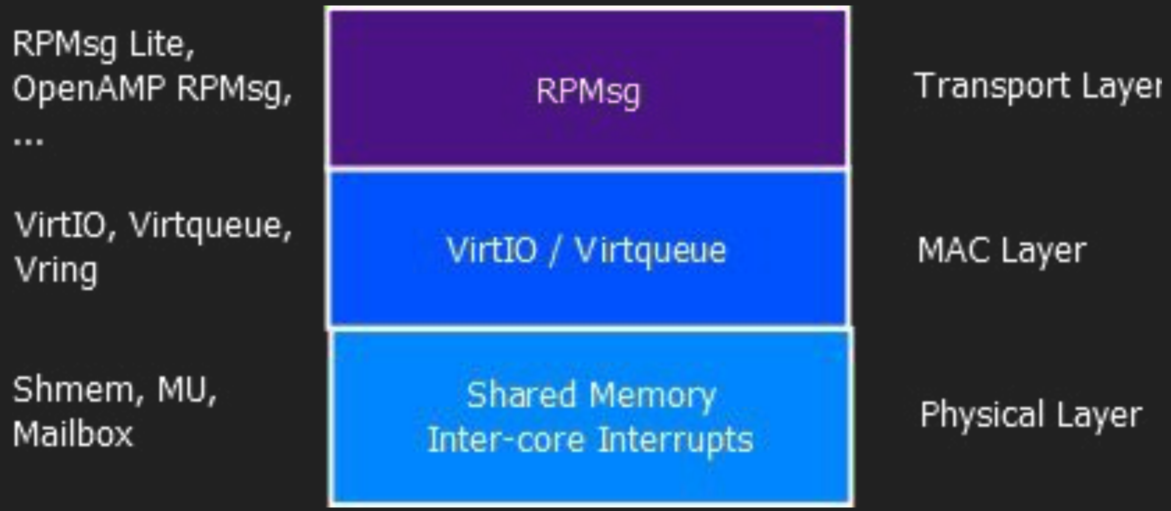




- Strong isolation
- Hides non-trivial AMP details (e.g. resource assignment, inter-core communication)
- Security and robustness
- Overhead of a software layer

- Achieve best performances by running natively
- Boot sequence complexity
- Harder to debug

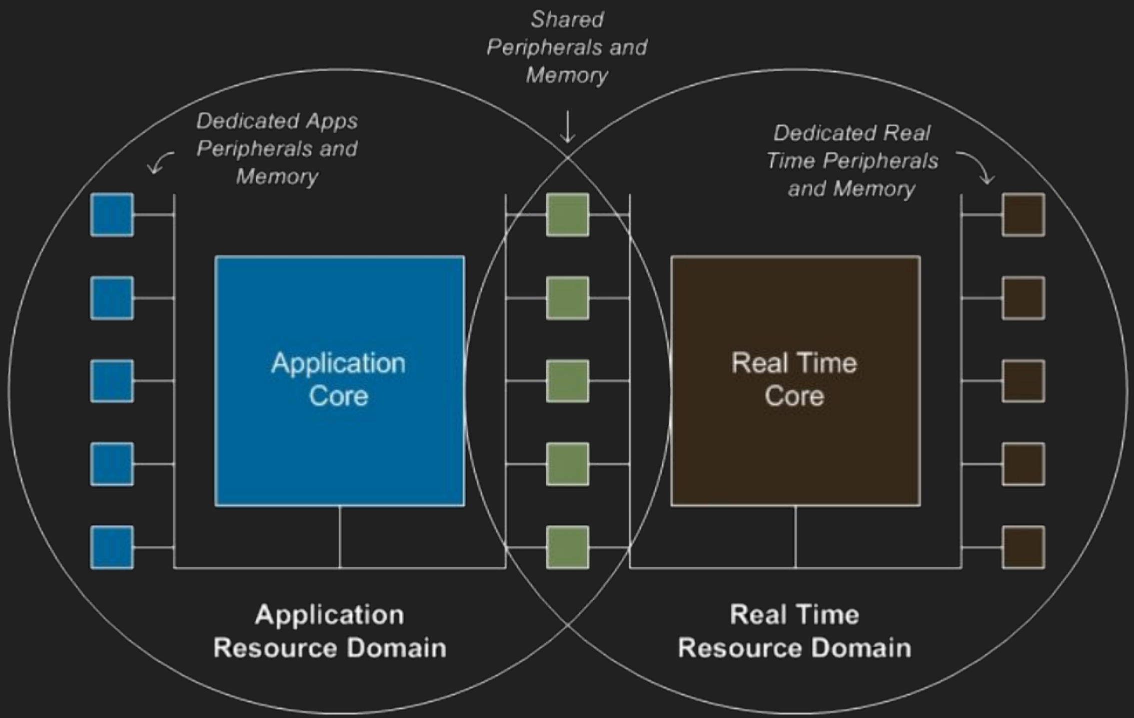
Interprocessor Communication



NXP i.MX7 overview

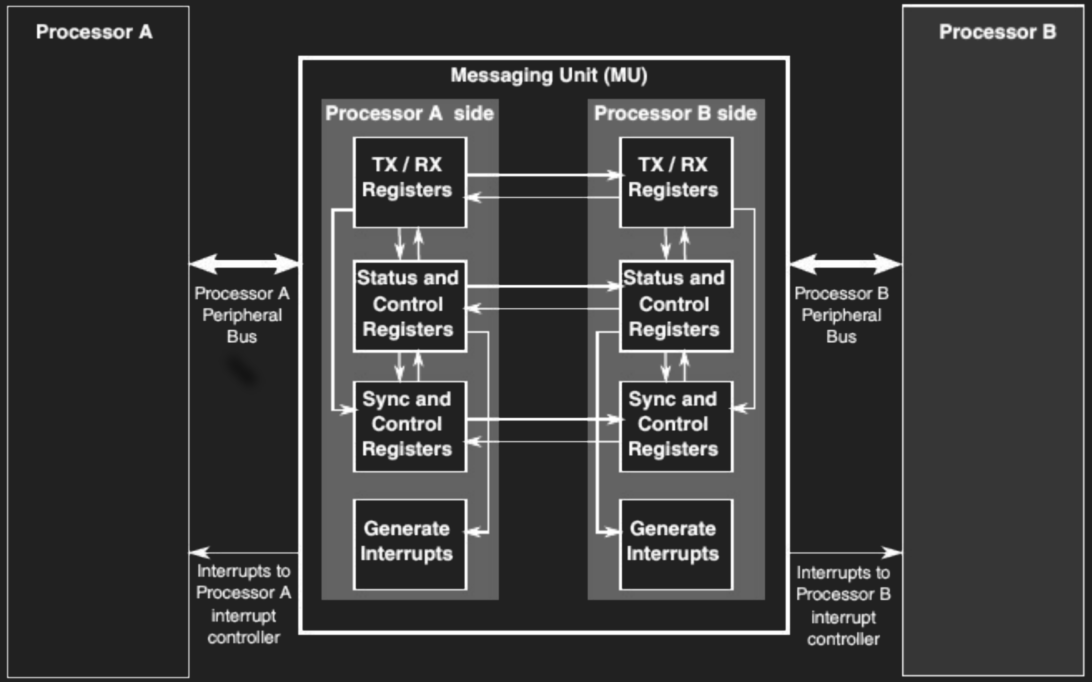
- Cortex-A7 core + Cortex-M4 core
- Master - Slave architecture
  - A7 is the master
  - M4 is the slave
- Inter processor communication
  - MU - Messaging Unit
  - RPMsg component (OpenAMP framework)
- Safe sharing of resources
  - RDC - Resource Domain Controller

NXP i.MX7 - RDC



Shared Peripherals and Memory
Dedicated Apps Peripherals and Memory
Dedicated Real Time Peripherals and Memory
Application Core
Real Time Core
Application Resource Domain
Real Time Resource Domain

NXP i.MX7 IPC - MU



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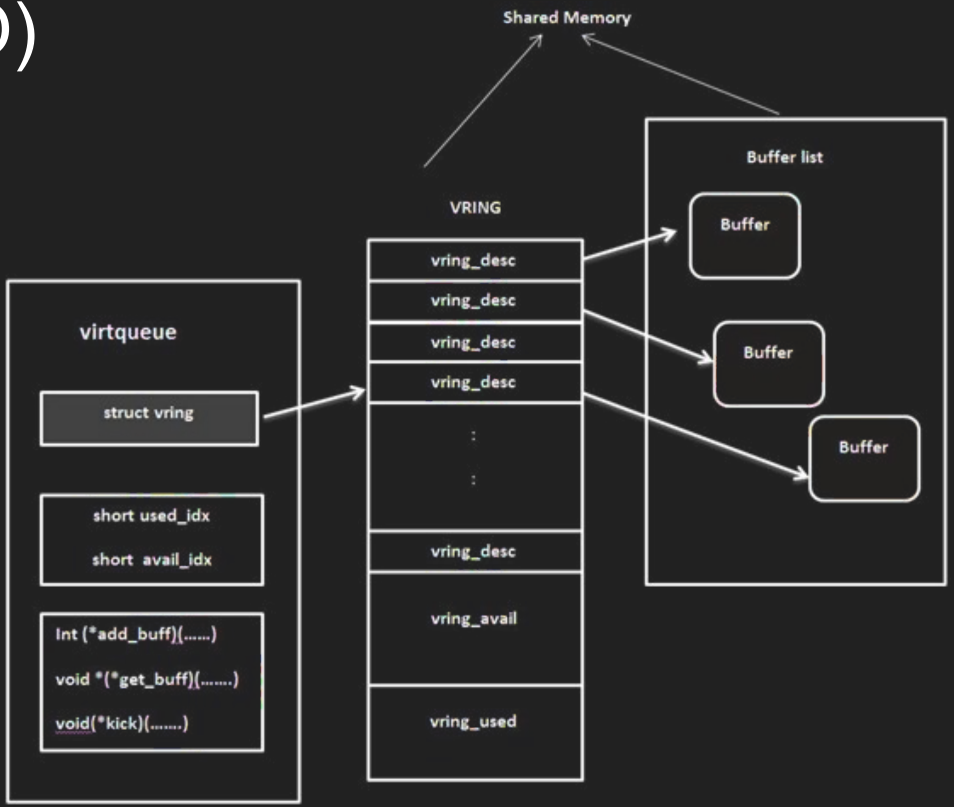
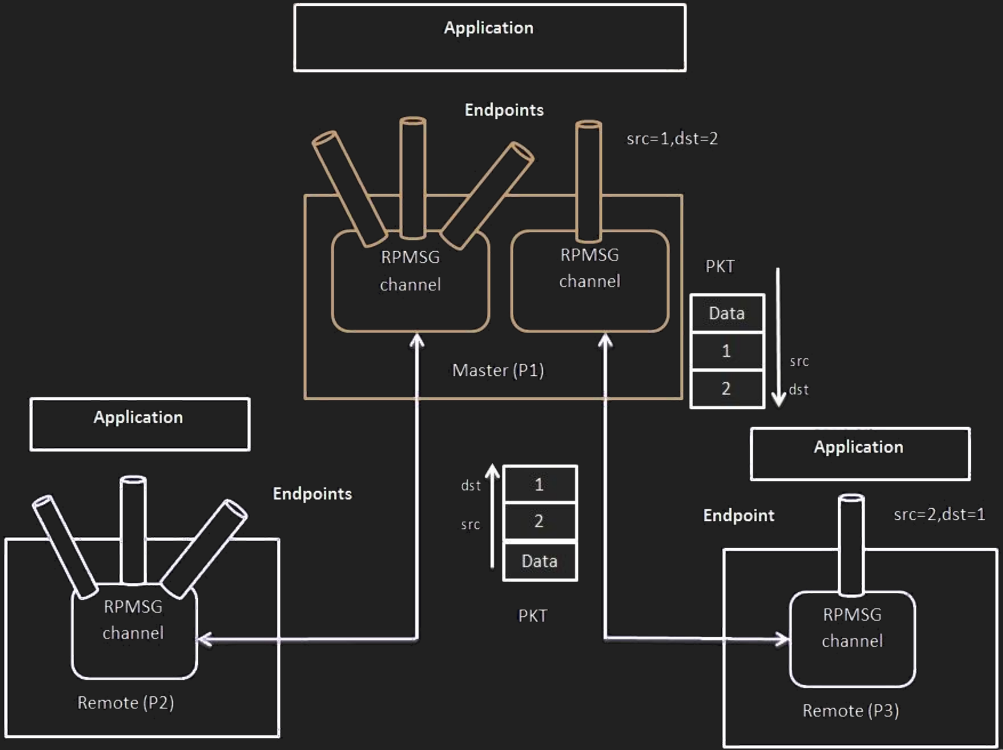
MAC (VirtIO)

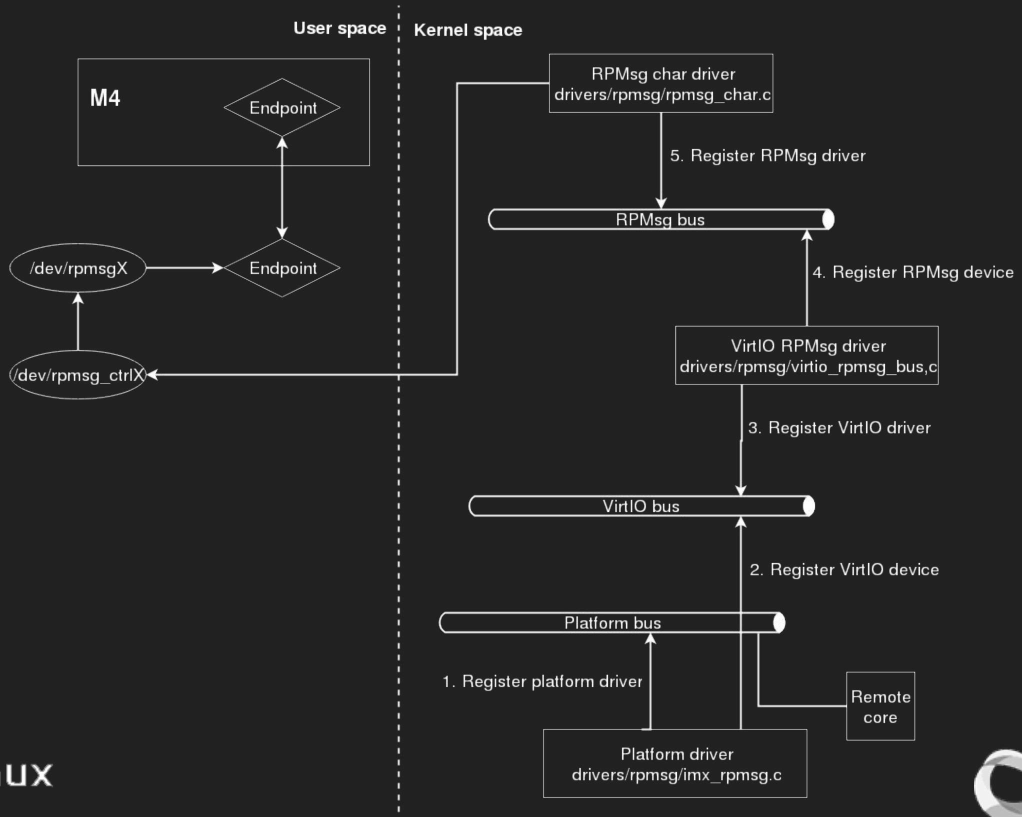


Shared Memory
Buffer list
VRING
Buffer
vring_desc
vring_desc
Buffer
vring_desc
vring_desc
virtqueue
struct vring
Buffer
:
:
short used_idx
short avail_idx
vring_desc
vring_avail
Int (*add_buff)(......)
void *(*get_buff)(.......)
void(*kick)(.......)
vring_used

The OpenAMP framework - RPMsg



RPMsg on Linux



Hybrid Linux/FreeRTOS Demo

Demo Goal:

- IMU sensor (I2C) read by MCU task
- Calculate objective function (module of acc, mag, gyro vectors)
- Log/plot sensor samples on MPU
- Safely recover from a kernel panic

Hardware Setup

- Boundary Devices Nitrogen 7, Toradex Colibri i.MX7 SOM
  - NXP i.MX7D processor - ARM dual Cortex-A7 + ARM Cortex-M4
  - Segger J-Link Probe

Cortex M4 Bring Up (1)

Environment setup:

- Download FreeRTOS sources
  https://github.com/boundarydevices/freertos-boundary.git
- Download GNU ARM Embedded Toolchain
  https://developer.arm.com/open-source/gnu-toolchain/gnu-rm/download
- Example applications for Cortex-M4 are located in the `examples/imx7d_nitrogen7_m4/` folder
- Scripts for building both debug and release binaries are available in the `armgcc` subfolder

Cortex M4 Bring Up (2)

M4 Binary application can be loaded on the Cortex-M4 in different ways:

- U-Boot - ums gadget + `m4update`
- using remoteproc framework (linux userspace)
- using `imx-m4fwloader` from NXP (linux userspace): https://github.com/codeauroraforum/imx-m4fwloader

M4 code can be linked and loaded to one of the following:

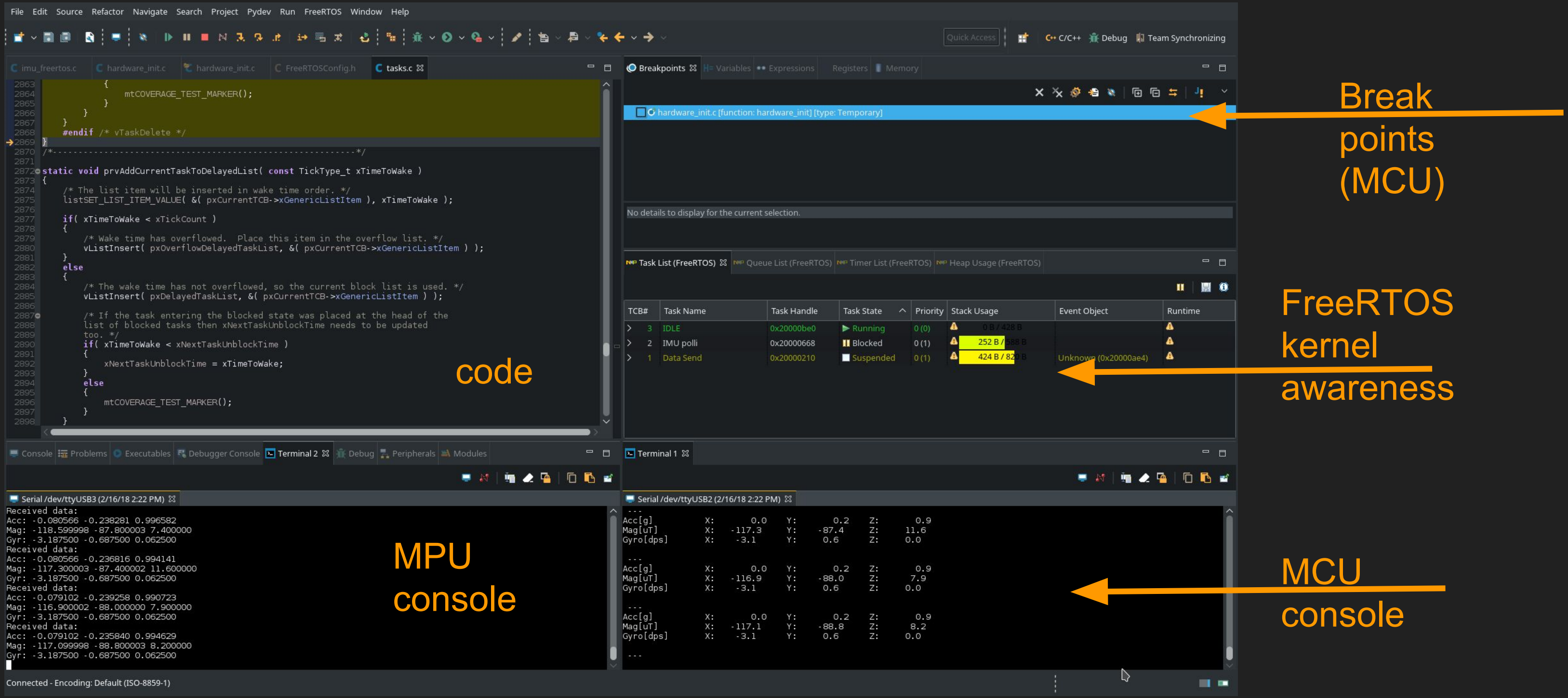
- TCM - 32KB (preferred)
- OCRAM - 32KB
- DDR - up to 1MB
- QSPI Flash - 128KB

IDE Setup

- Eclipse for C/C+
  - GNU MCU Eclipse : plugins and tools for embedded ARM development - https://marketplace.eclipse.org/content/gnu-mcu-eclipse
- GDB
- J-Link scripts for iMX7D for debugging both Cortex-A7 cores and Cortex-M4 - https://wiki.segger.com/IMX7D
- FreeRTOS Kernel Awareness plugin from NXP http://freescale.com/lgfiles/updates/Eclipse/KDS
- ARM DS-5 (not free)
- Sourcery Codebench (not free)

Workbench

kynetics
enjoy the art of coding



Demo Parameters

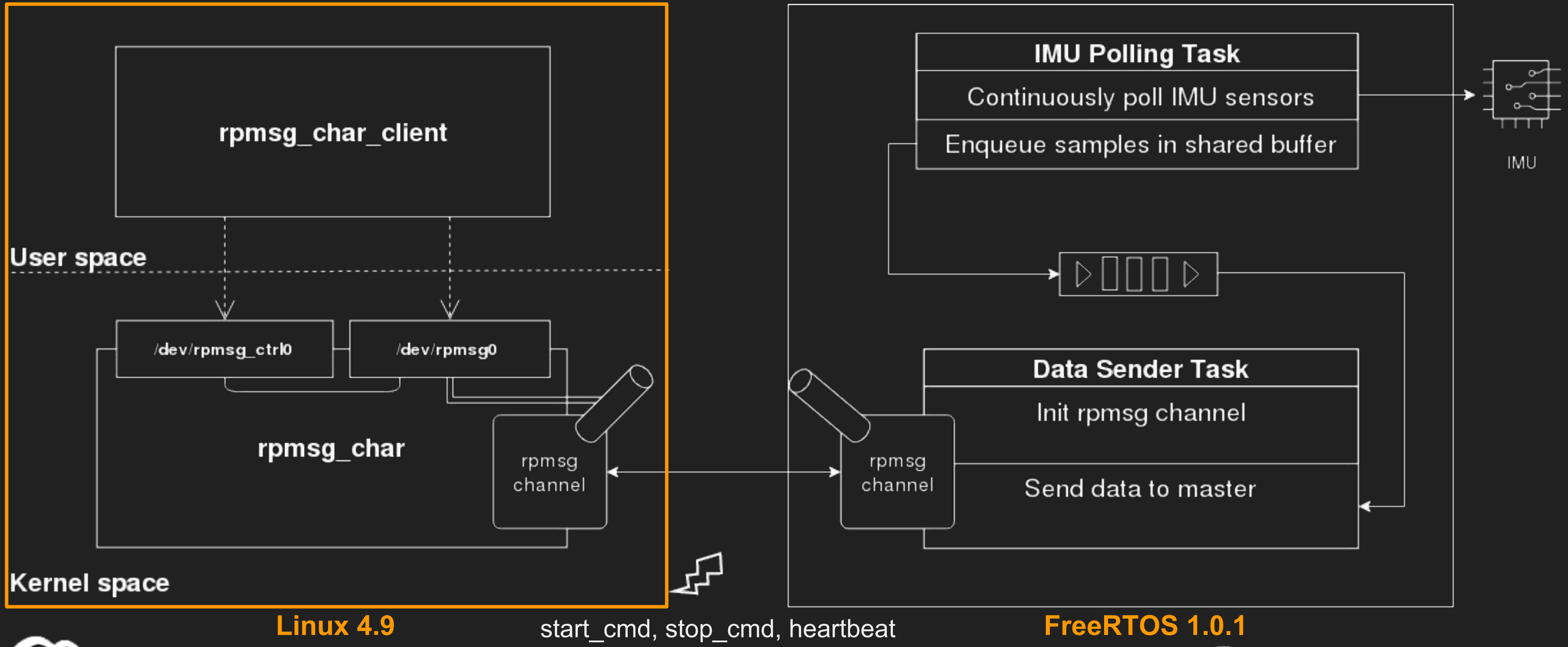
Remote core:

- Sample IMUs every 10ms
- Calculate the objective function on MCU (module of vectors)
- Buffer of 300 elements = 3Kb (stored TCM Memory only 32 Kb)
- Items (12 byte each) are dequeued and sent to master 10 at a time every 100 ms

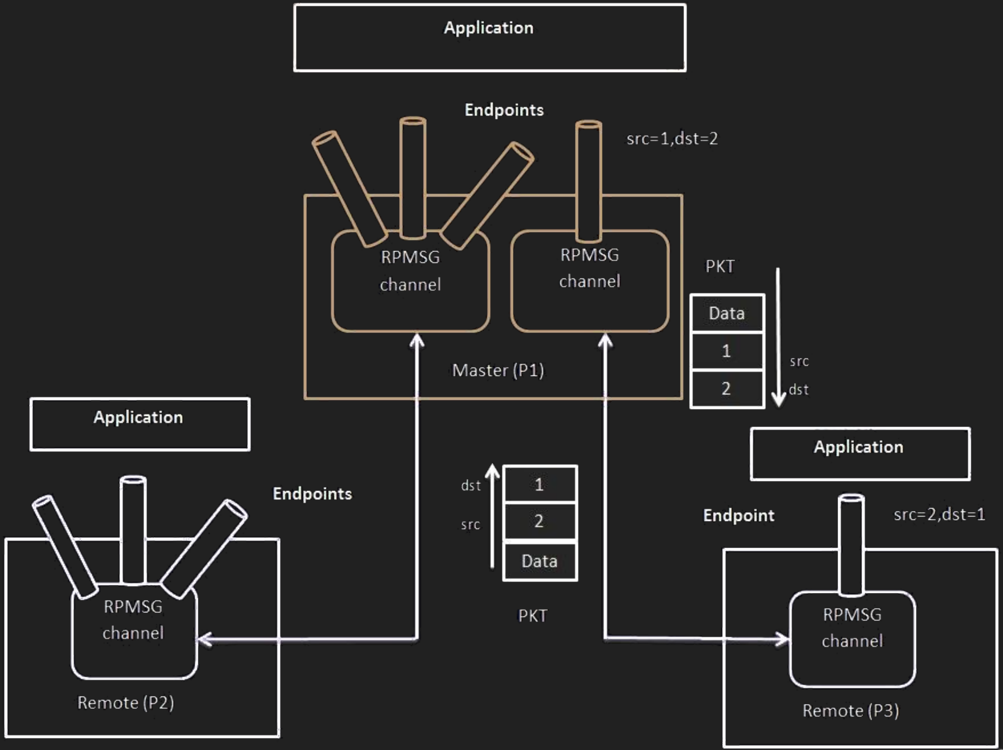
Master core:

- Master reads incoming samples by polling the character device

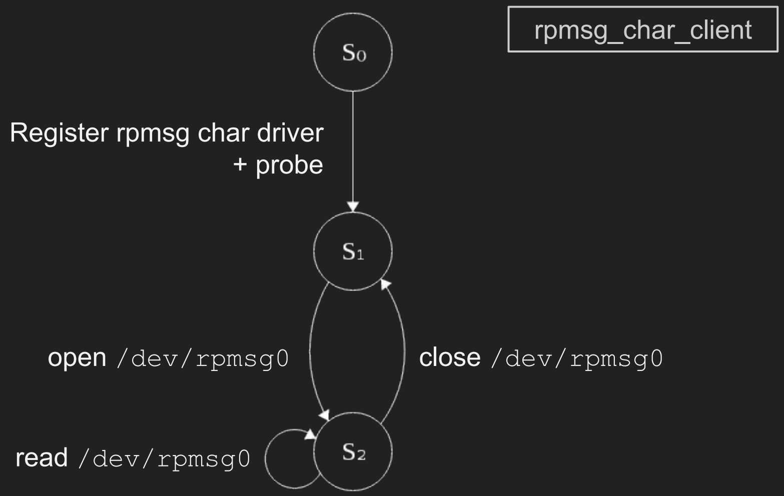
Architecture Overview



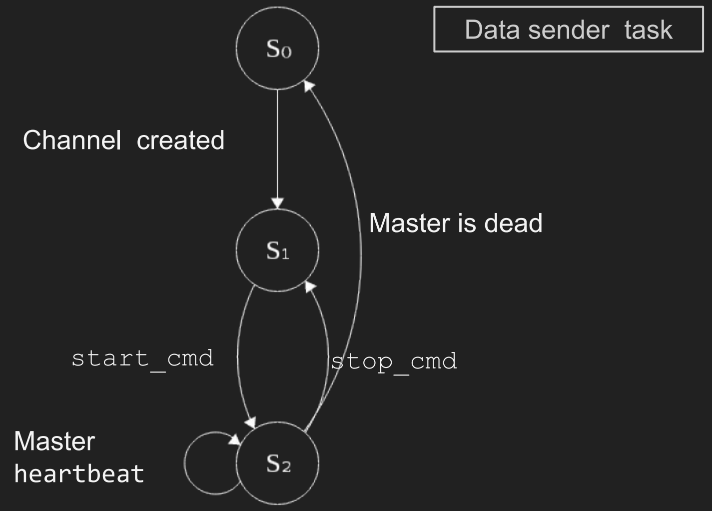
The OpenAMP framework - RPMsg



Control Flow (2 cores)



- S0 RPMsg channel is down
- S1 RPMsg channel is up, /dev/rpmsg0 is created
- S2 RPMsg channel is up, endpoint created, data is dumped into a log file



- S0 RPMsg channel is down
- S1 RPMsg channel is up (sampling IMU sensor, buffering data)
- S2 RPMsg channel is up, sending data to master core, (sampling IMU sensor, buffering data),

What if Linux Kernel Panics

- Kexec: system call to load and boot into another kernel from the currently running kernel (4.9.74).
  - `crashkernel=128M [normal kernel cmdline]`
  - `irqpoll, nosmp, reset_devices [crash kernel cmdline]`
  - `--load-panic option`
- Kdump: Linux mechanism to dump machine memory content on kernel panic.
- Kexec/Kdump support on ARM platforms is still experimental

Video of the Demo

VIDEO

Pitfalls

- Before announcing the remote service, MCU checks whether master is up. If notification arrives too early (*virtqueue kick* function call) when booting crash kernel the system might hang
- Sometimes kexec still hangs and fails to soft-reboot - more frequent when streaming continuously instead of sending data bursts (but we don’t know why)

References

- OpenAMP project page: https://github.com/OpenAMP/
- Asymmetric multiprocessing and embedded linux (ELC 2017): https://elinux.org/images/3/3b/NOVAK_CERVENKA.pdf
- Mantainers:
  - Open-amp:
    - Wendy Liang
  - RPMsg (Linux)
    - Ohad Ben-Cohen
    - Bjorn Andersson
  - Kexec (Linux)
    - Eric Biederman
  - Kdump (Linux)
    - Dave Young
    - Baoquan He

Q/A