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Realtime Linux uncovered

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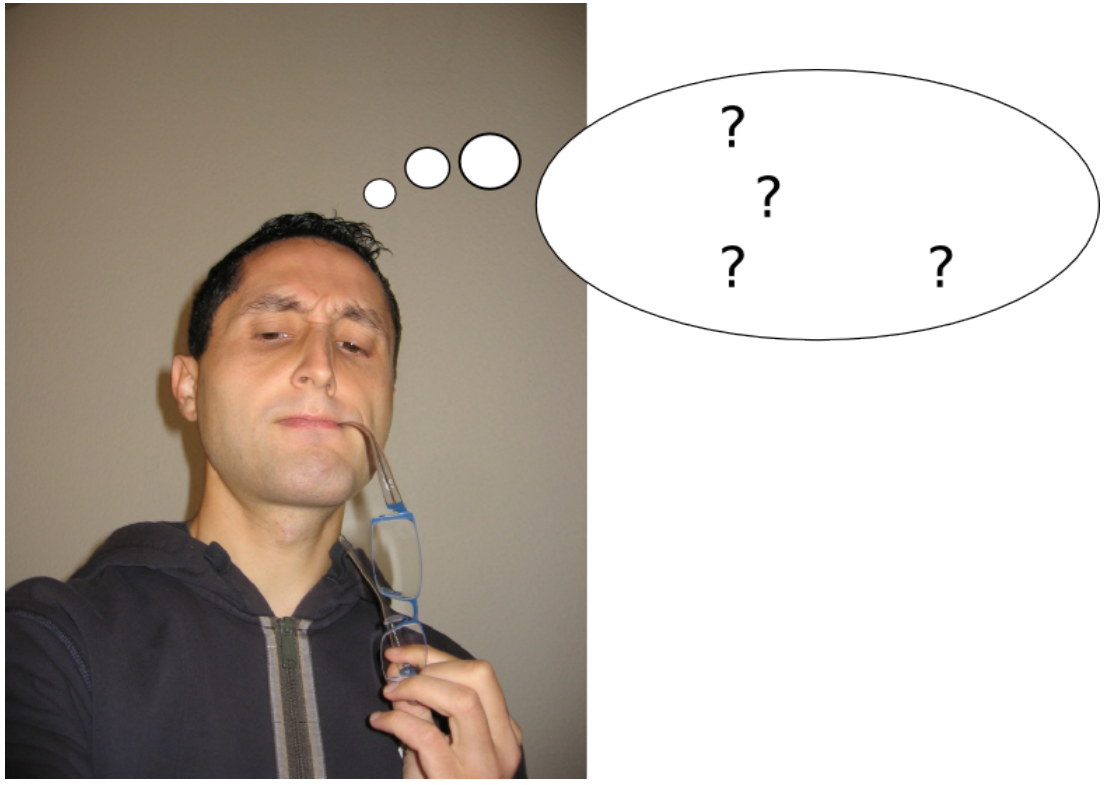
Overview

1. What is Realtime?
2. Linux and Realtime - History and approaches
3. Preempt RT
4. Results: Which latencies can be achieved with the different approaches?
5. Conclusion

What is Realtime?

Fast execution time?



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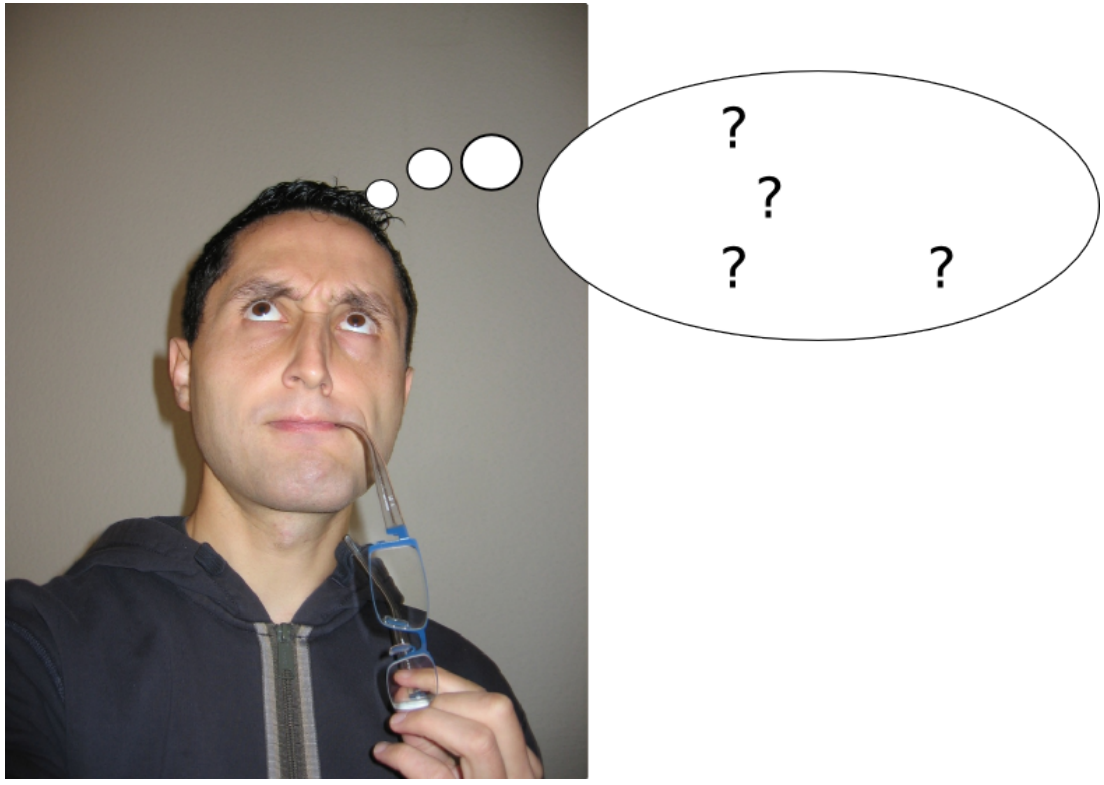
What is Realtime?

Performance?



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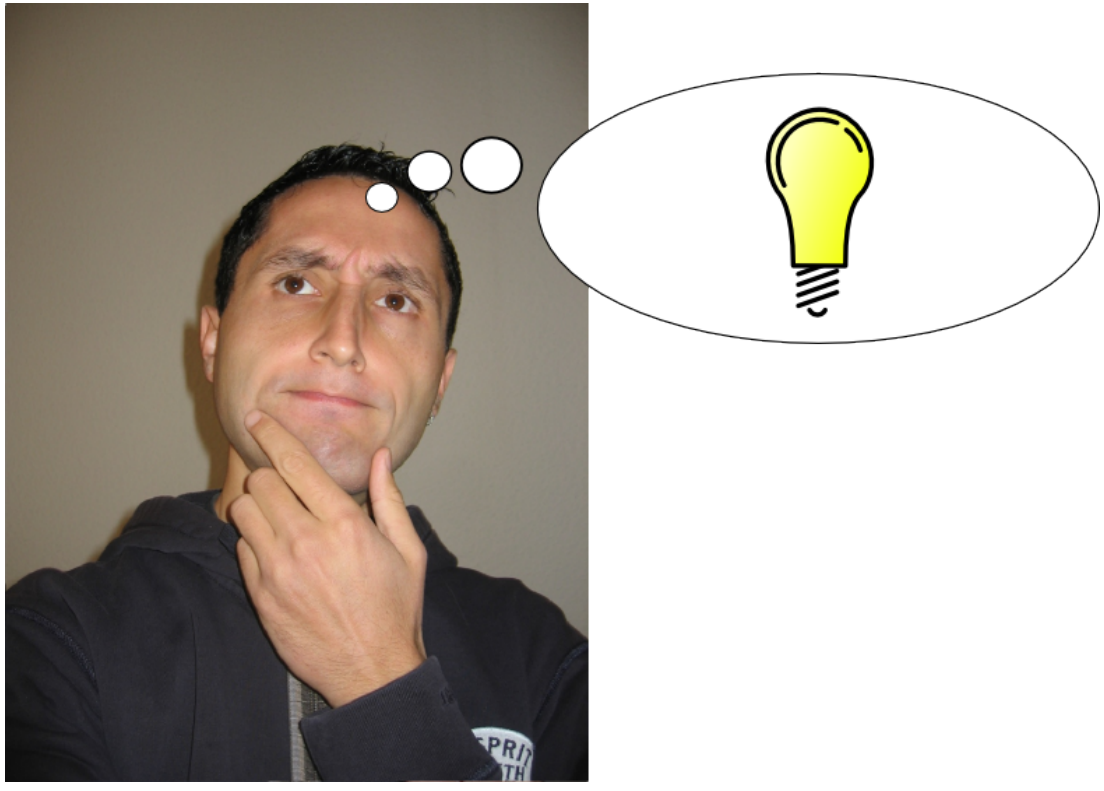
What is Realtime?

It's all about DETERMINISM!



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What is Realtime?

- Correctness means execution at the correct time
- Missing the timeslot will lead to an error condition

Realtime

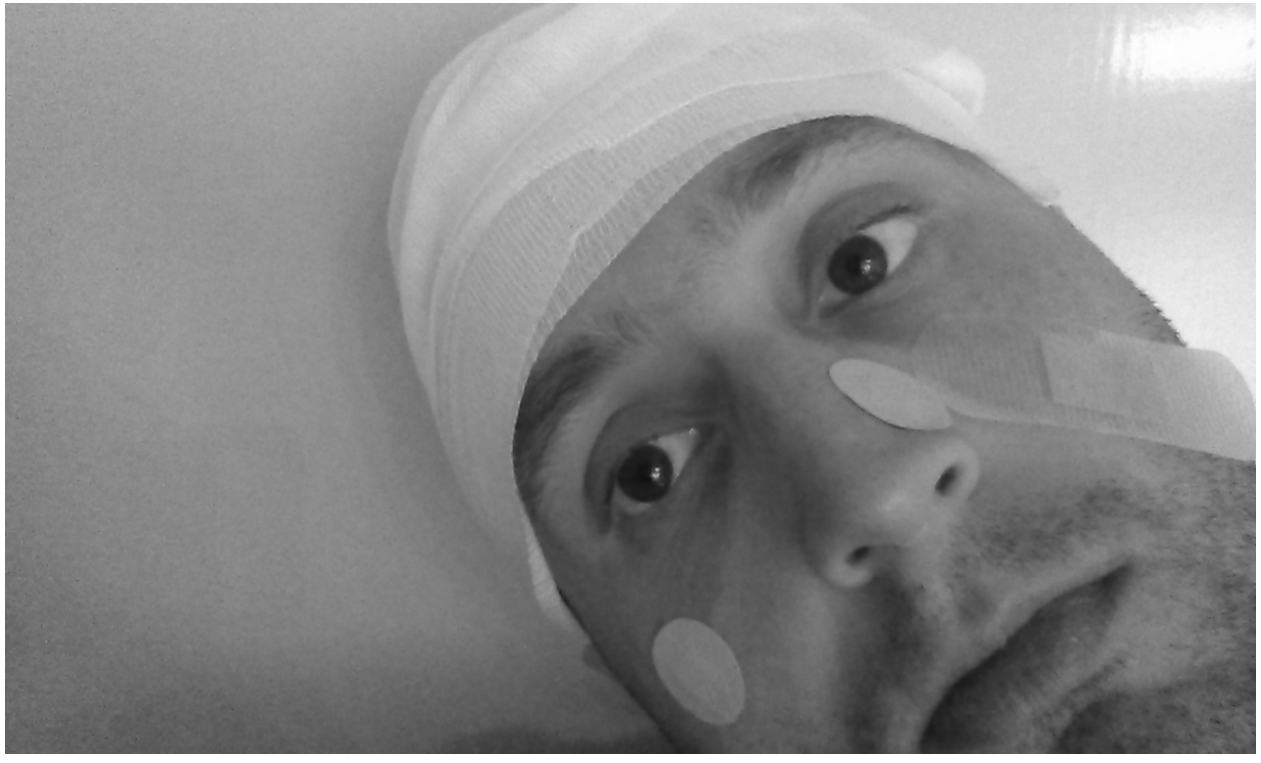
Remember!

Missing the timeslot will lead to an error condition

Realtime

Missing the timeline

will cause a damage to your machine or even a person might get hurt:



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What about "Softrealtime"?

...PLEASE PLEEAAASSEEE forget about this word!!! :)

Who is using it?

- industry / automation
- multimedia systems
- aerospace
- financial services
- ...

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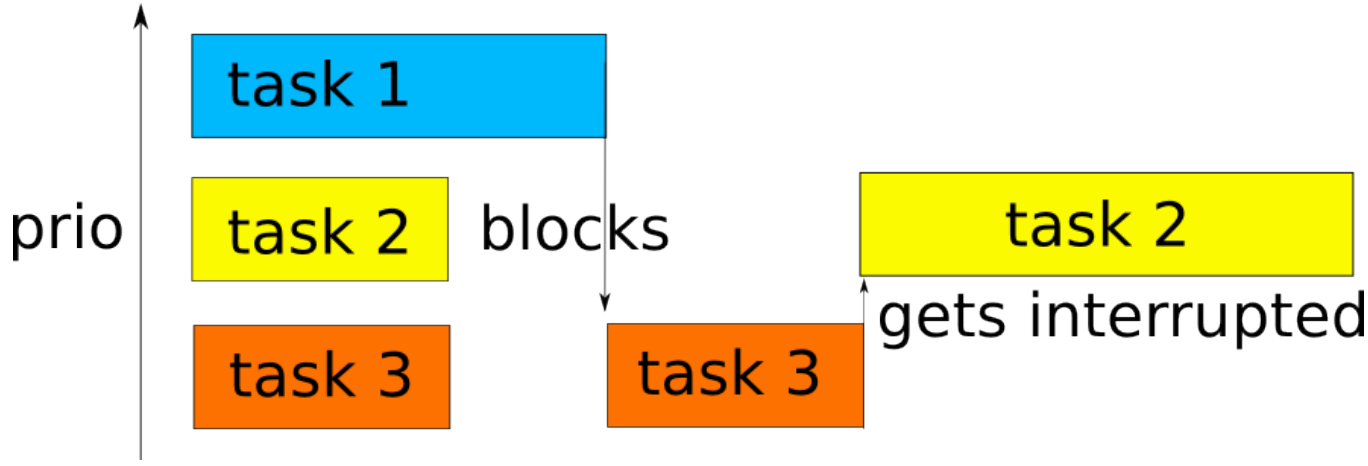
Requirements

- Deterministic timing behaviour
- Preemption
- Priority Inheritance / Priority Ceiling

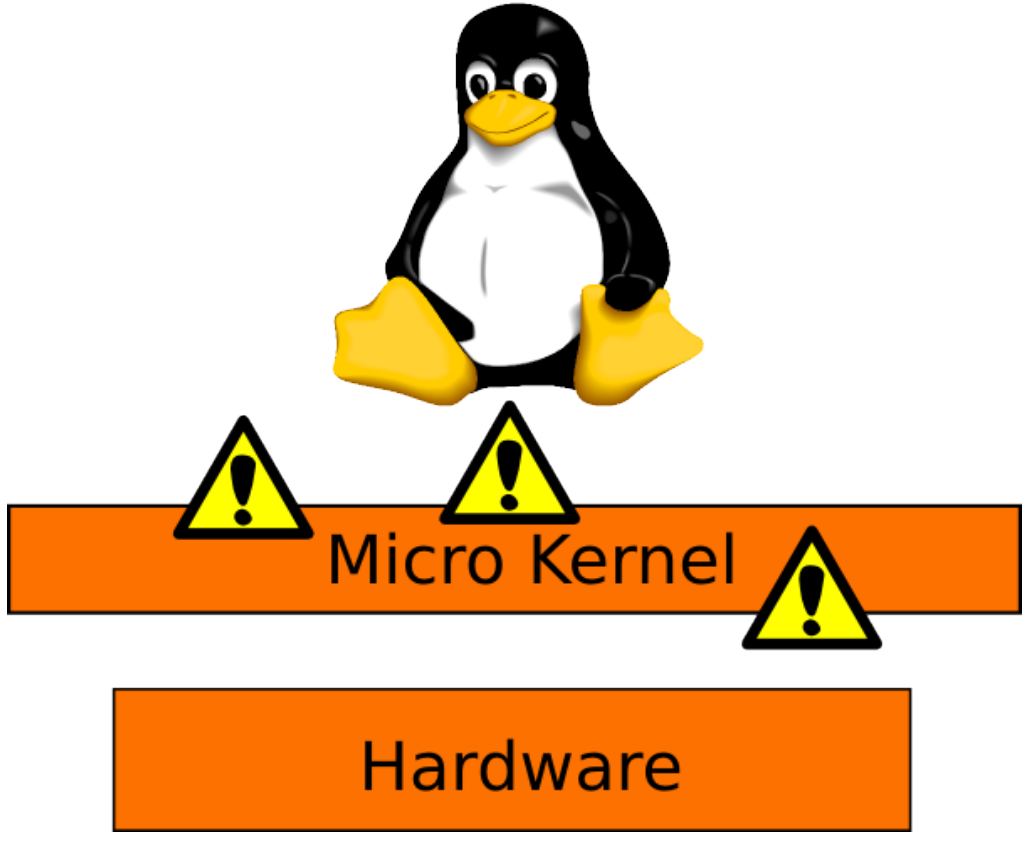
Priority Inversion



Approaches

- Dual-Kernel
- In-Kernel / Single Kernel

Dual-Kernel



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Single-Kernel

Hardware

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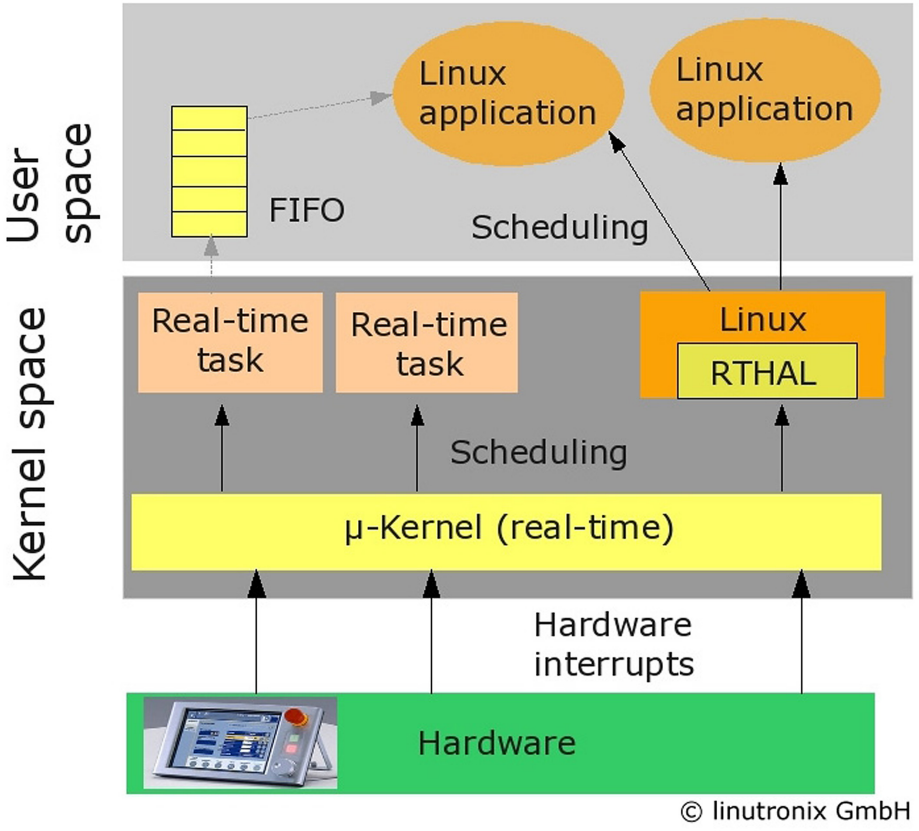
RTAI

- Prof. Paolo Mantegazza, University of Milano
- Dual-Kernel approach
- Realtime in kernelspace
- Realtime in userspace very limited
- Design goal: Lowest latencies
- Supported platforms: x86, x86_64, and a couple of ARM platforms

RTAI


User space
Kernel space
Linux application
Linux application
FIFO
Scheduling
Real-time task
Real-time task
Linux
RTHAL
Scheduling
µ-Kernel (real-time)
Hardware interrupts
Hardware
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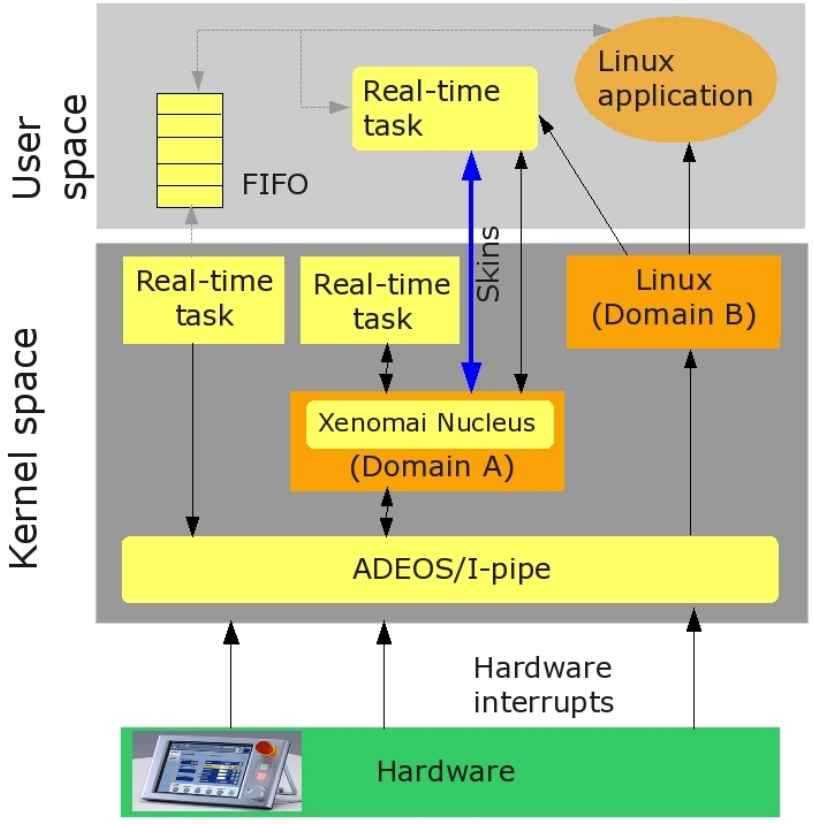
Xenomai

- Founded 2001
- Realtime in userspace
- Skins can emulate the API of different RTOSes
- Dual-Kernel approach
- Supported platforms: x86, x86_64, PowerPC, ARM, ia64

Xenomai


User space
Kernel space
FIFO
Real-time task
Linux application
Skins
Real-time task
Real-time task
Linux (Domain B)
Xenomai Nucleus
(Domain A)
ADEOS/I-pipe
Hardware interrupts
Hardware

Known issues of dual-kernel approaches

- Special API
- Special tools and libraries
- Microkernel needs to be ported for new HW and new Linux versions
- Bad scaling on big platforms (which is a problem for server people...Remember the financial service example)

Preempt RT

- In-Kernel approach
- Founded by: Thomas Gleixner, Ingo Molnar
- POSIX realtime
- A lot of the features already made it into "Mainline"
- Huge community
- Highly accepted in the community

How Preempt RT brings Realtime to Linux?

Remember once again...

Preemption is the most important requirement for a Realtime System

How Preempt RT brings Realtime to Linux?

- Locking Primitives: It introduces the "sleeping spinlocks"
- Interrupt Handlers run in a kernel thread
- Introduces "CONFIG_PREEMPT_RT_FULL"
- To make the story short: The main aim of the Preempt RT patch is to minimize the amount of kernel code that is non-preemptible

Sleeping spinlocks

- In Preempt RT spinlocks are mapped onto sleeping spinlocks, and raw spinlocks retain their behavior
- In a non Preempt RT preemption model spinlocks are mapped onto raw spinlocks

Threaded interrupt handlers

- Preempt RT forces threaded interrupt handlers
- To force an interrupt handler to be run in IRQ context it has to be marked with IRQF_NO_THREAD
- In mainline this behaviour can also be forced with the "threadirqs" commandline

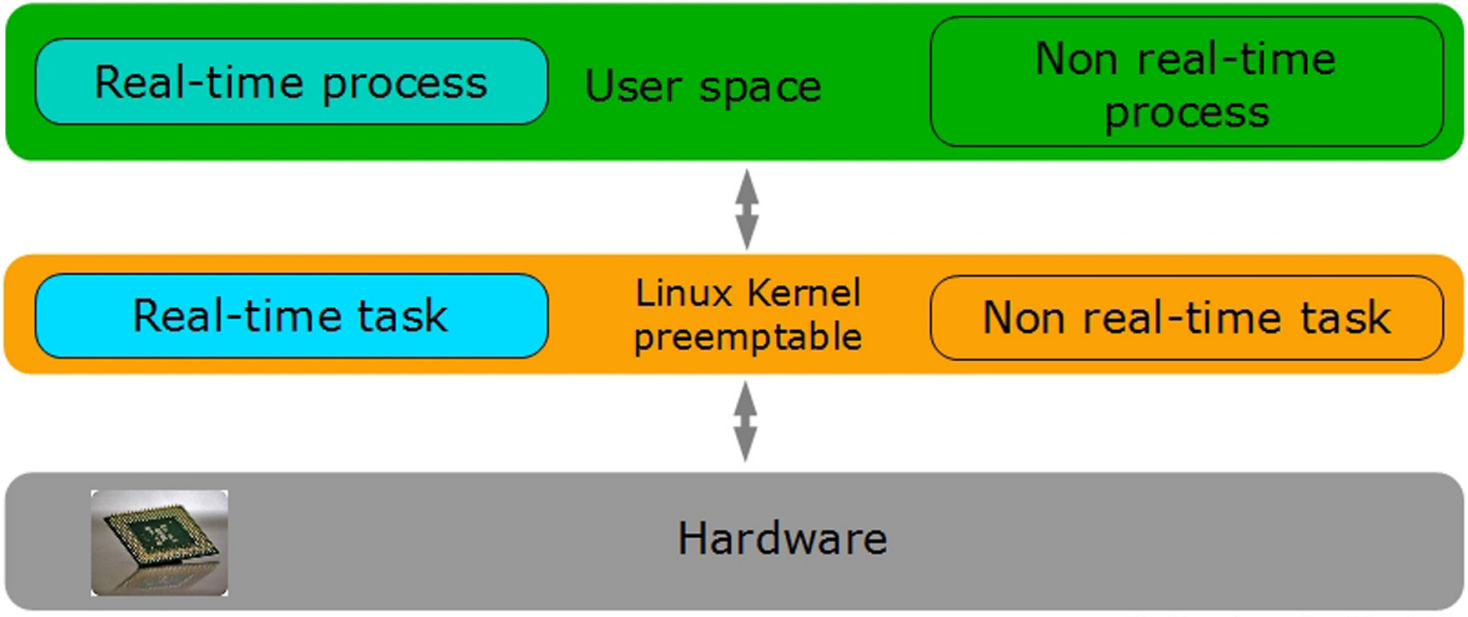
Threaded interrupt handlers

```
$ top
[...]
578 root    -51  0     0     0     0 S  0,0  0,0  0:00.00 irq/62-mei_me
[...]
```

So, how does userspace deal with it?

- Basically, userland won't even recognize ;-)
- Critical tasks use SCHED_FIFO or SCHED_RR
- Just follow the POSIX rules for realtime programming

Preempt RT



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Preempt RT and Mainline

"Controlling a laser with Linux is crazy, but everyone in this room is crazy in his own way. So if you want to use Linux to control an industrial welding laser, I have no problem with your using Preempt RT" - Linus Torvalds auf dem Kernel Summit 2006

Preempt RT and Mainline

- Patchset provided for certain kernels
- Patchset at: http://kernel.org/pub/linux/kernel/projects/rt/
- No funding for a couple of years
- In October 2015 LF announced the RTL Collaborative Project at ELCE in Dublin

Who is doing Preempt RT

- RTL Collaborative Project
- Mainline development, new kernels, ... done by Thomas Gleixner and his team at Linutronix
- Testing:
  https://ci-rt.linutronix.de
- Steven Rostedt maintains most of the stable trees
- Julia Cartwright maintains the v4.1 tree

Features which are already mainline

Just a few well known examples...Mentioning all features would take a presentation on its own ;-)

- High Resolution Timers
- Threaded Interrupt Handlers
- Tracing Infrastructure
- ...

Recently accomplished task

- CPU hotplug rework
- CPU hotplug locking rework

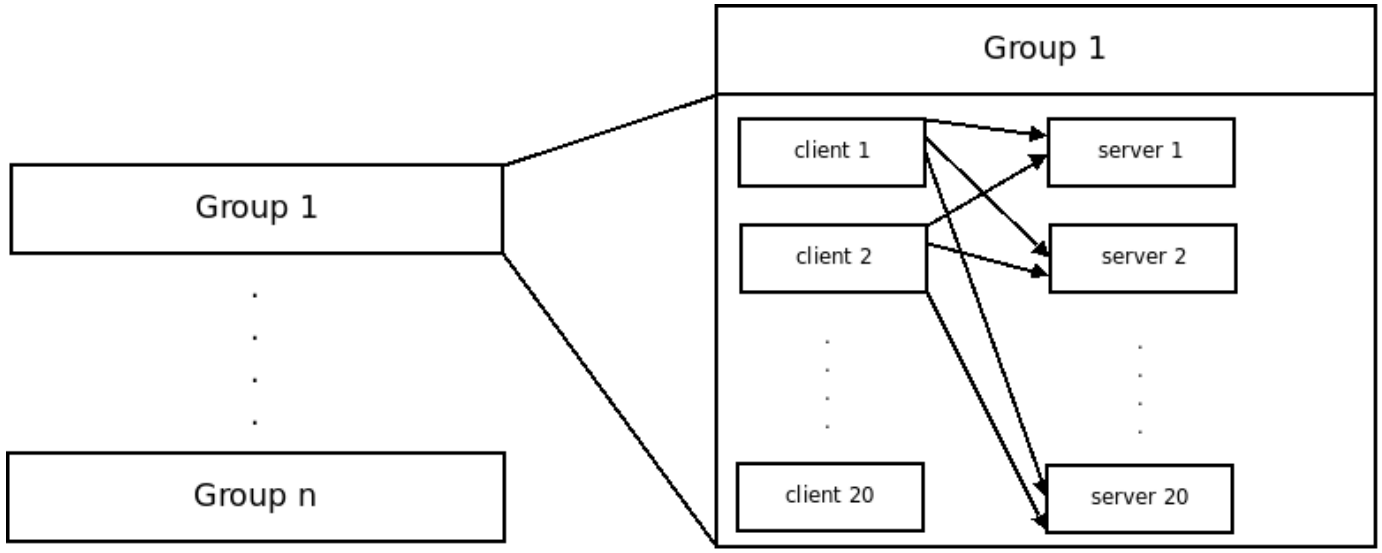
References

- More details about the mainlining status:
  "The Status of the Preempt-RT Patch" at ELCE 2017 by Sebastian Siewior
- Technical docs / Participation:
  https://wiki.linuxfoundation.org/realtime/start

Latency Measurements on a Cortex A9 platform

- ARM Cortex A9 SOC (Altera Cyclone V)
- System load: 100% CPU load with hackbench
- IRQ tests at 10 kHz with the OSADL Latency Box
- Test duration 12h

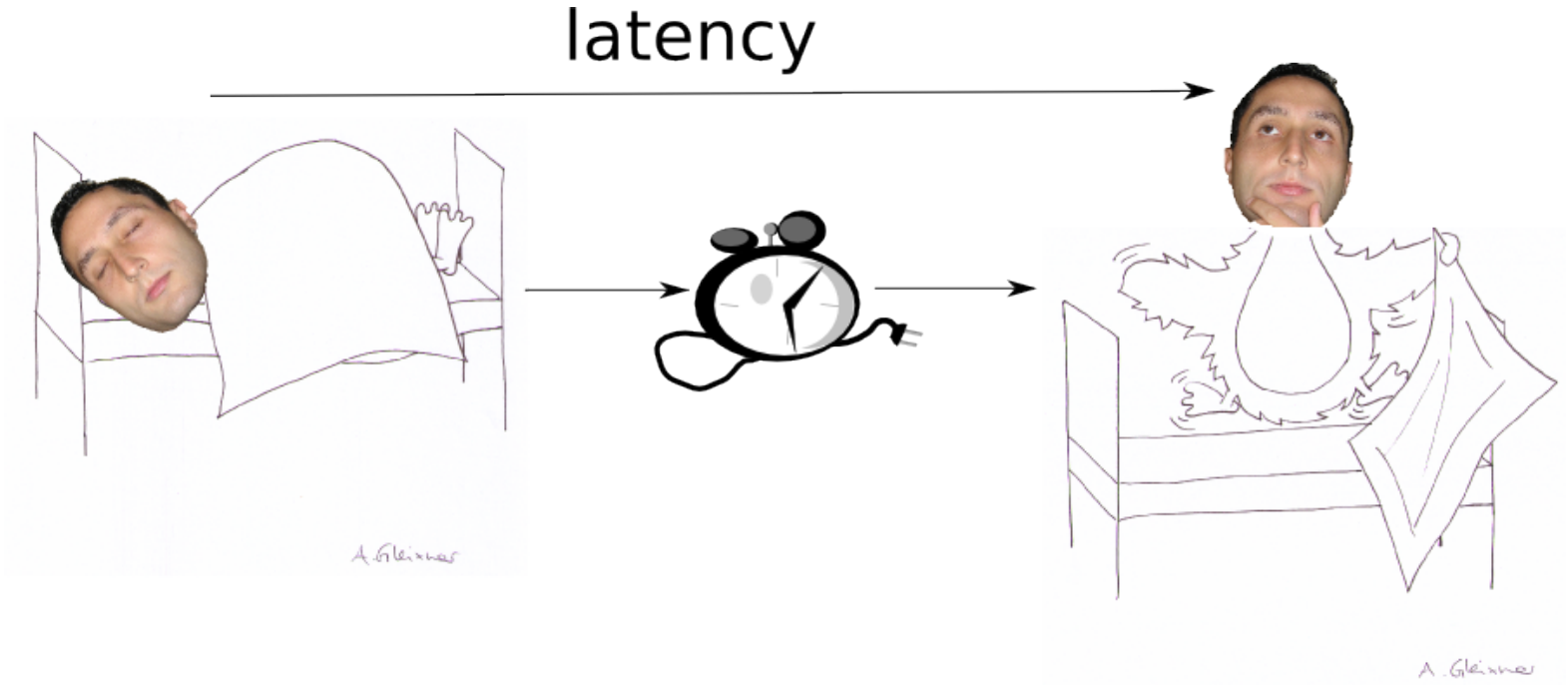
Load scenario: hackbench



- Starts n groups of 20 clients and 20 servers
- Each client sends 100 messages to each server via a socket connection

What has been measured?

Latency and Jitter



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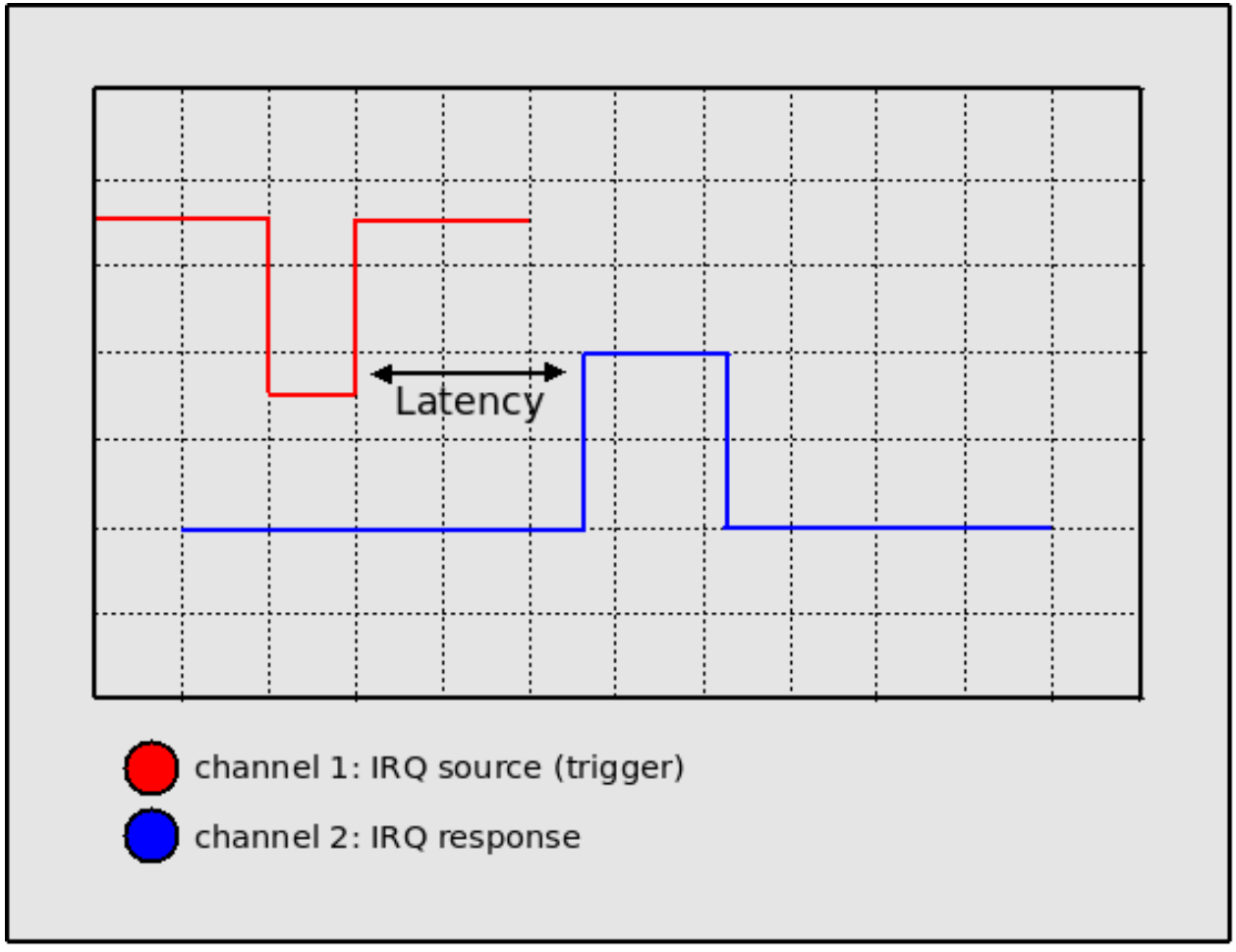
Latency measurement



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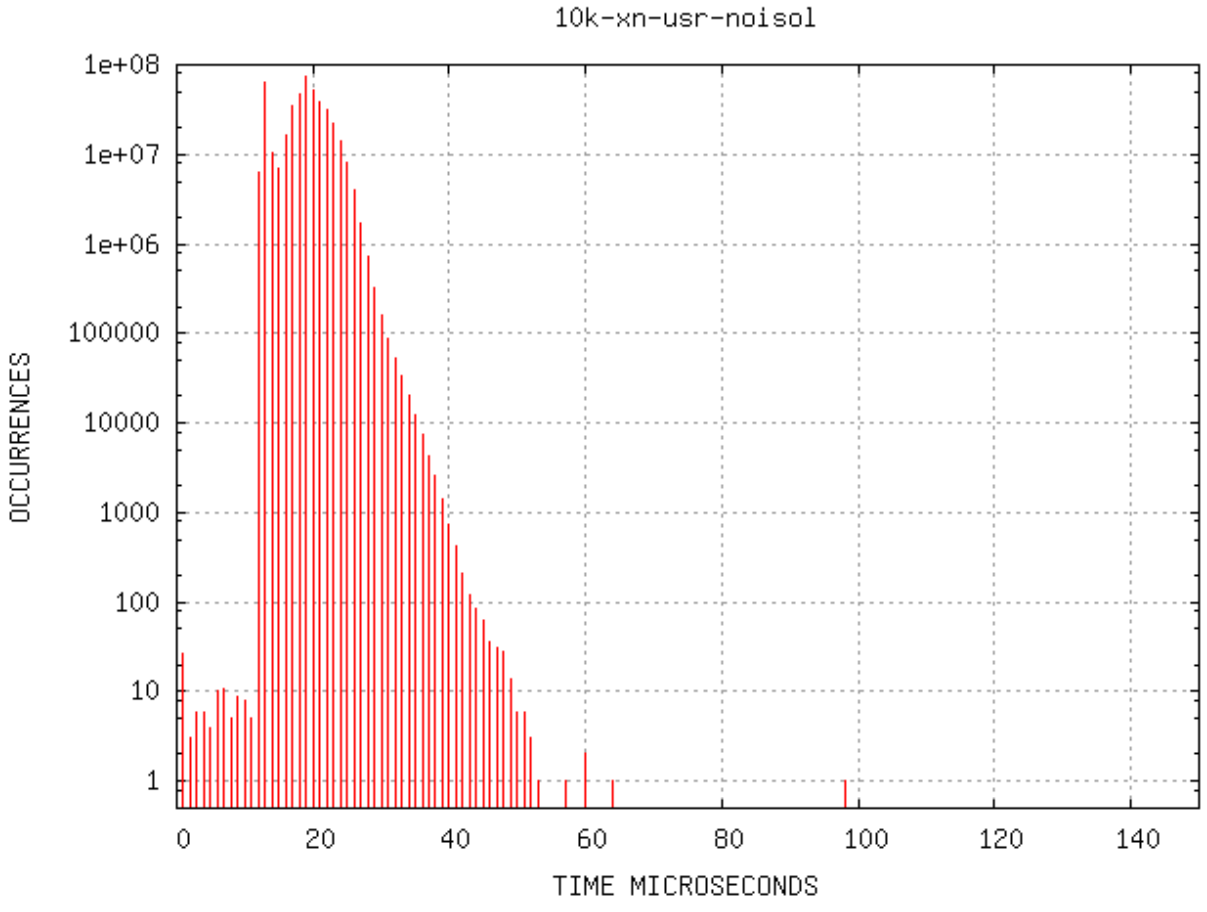
Userspace Latency: The most important usecase

The most important usecase is the latency of a userspace task. Usually a userspace task needs to be synced with an external event.

Xenomai: latency userspace task



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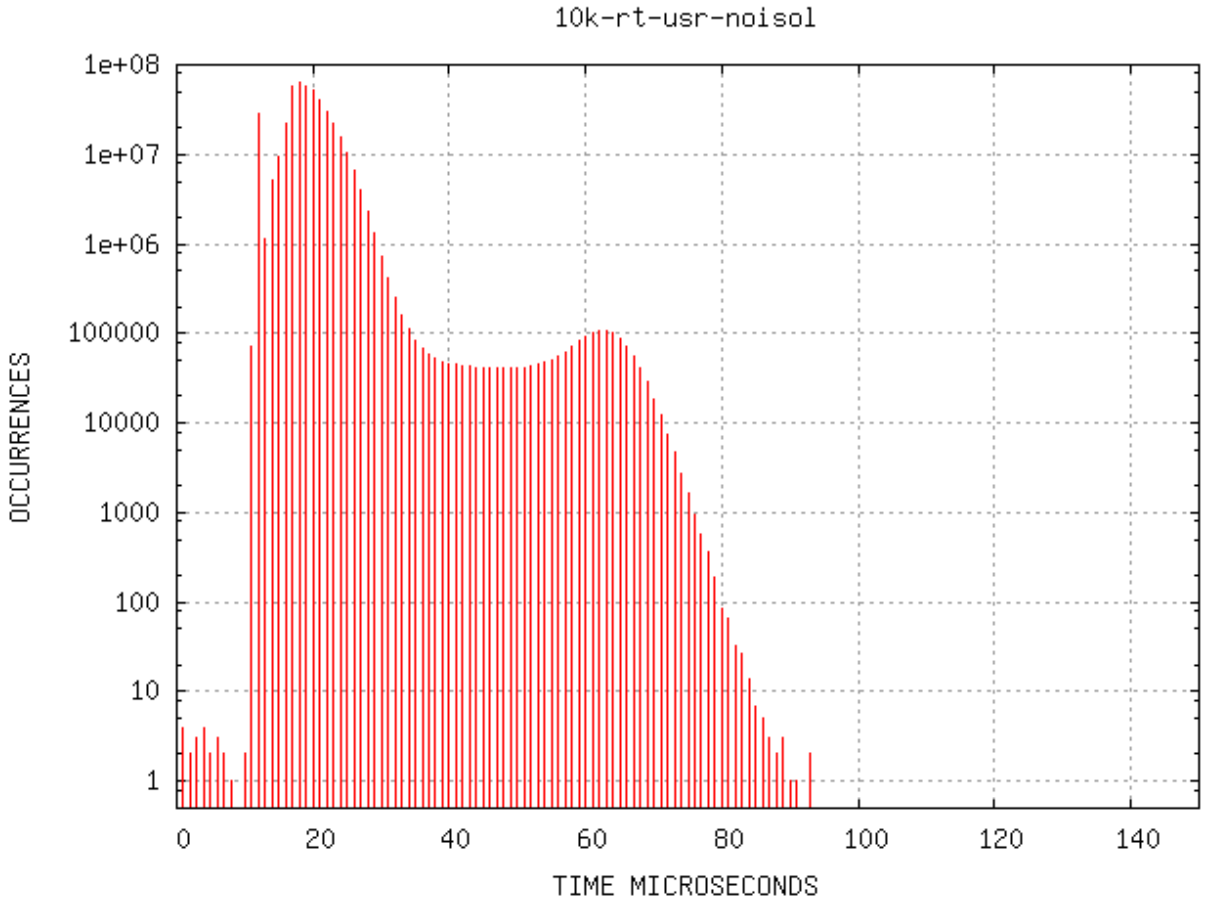
Preempt RT: latency userspace task



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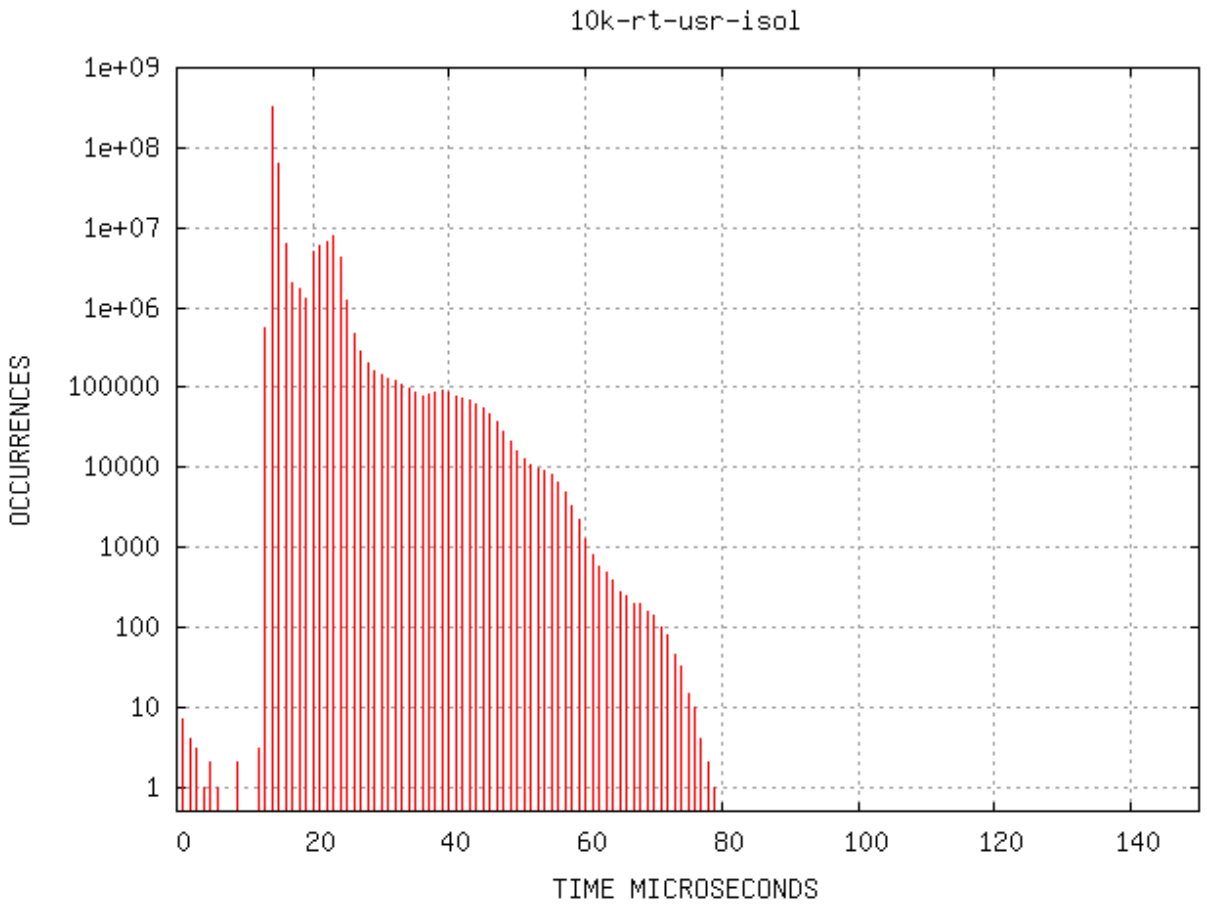
Preempt RT: latency userspace task (isolated CPU)



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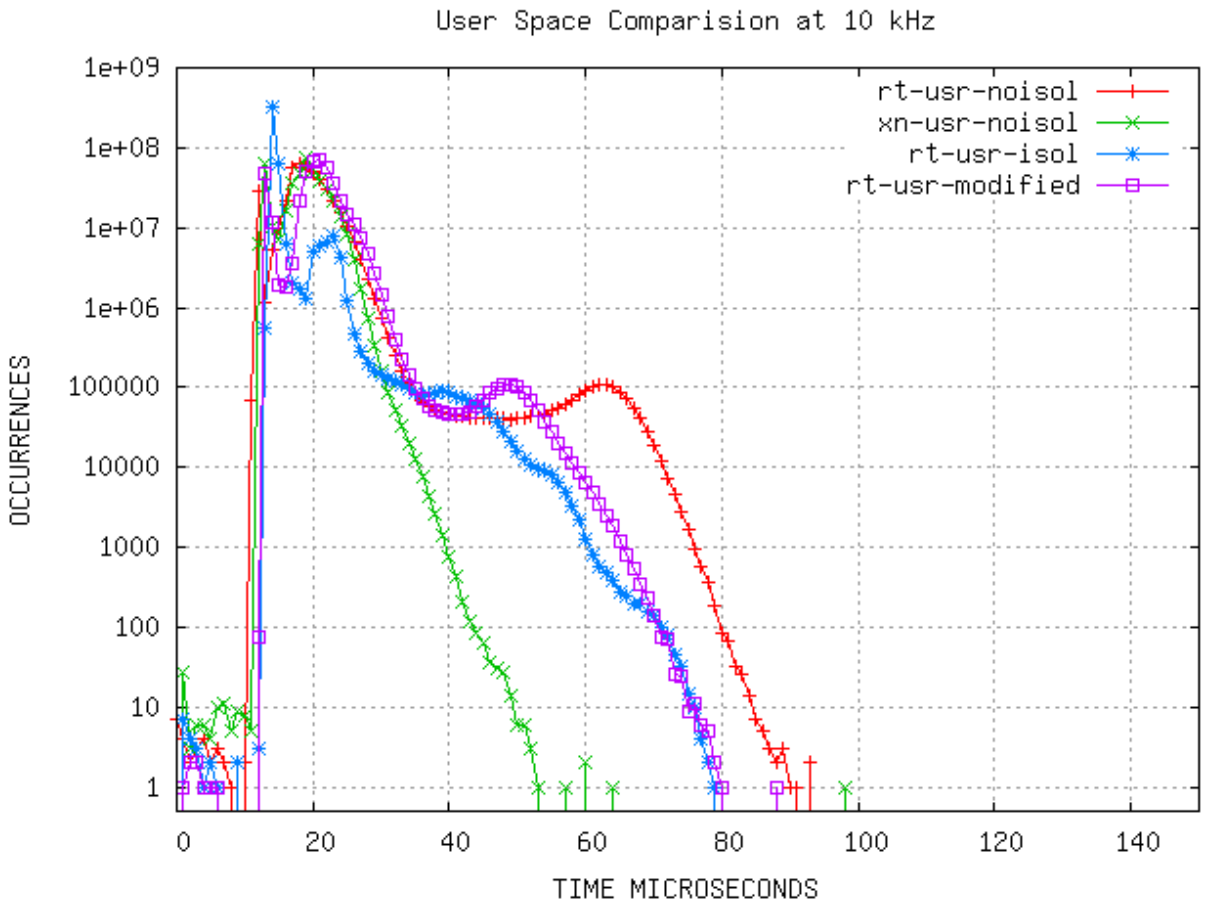
Latency userspace task - comparison



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Latency within the Kernel

...or how to compare apples with pears!! ;-)

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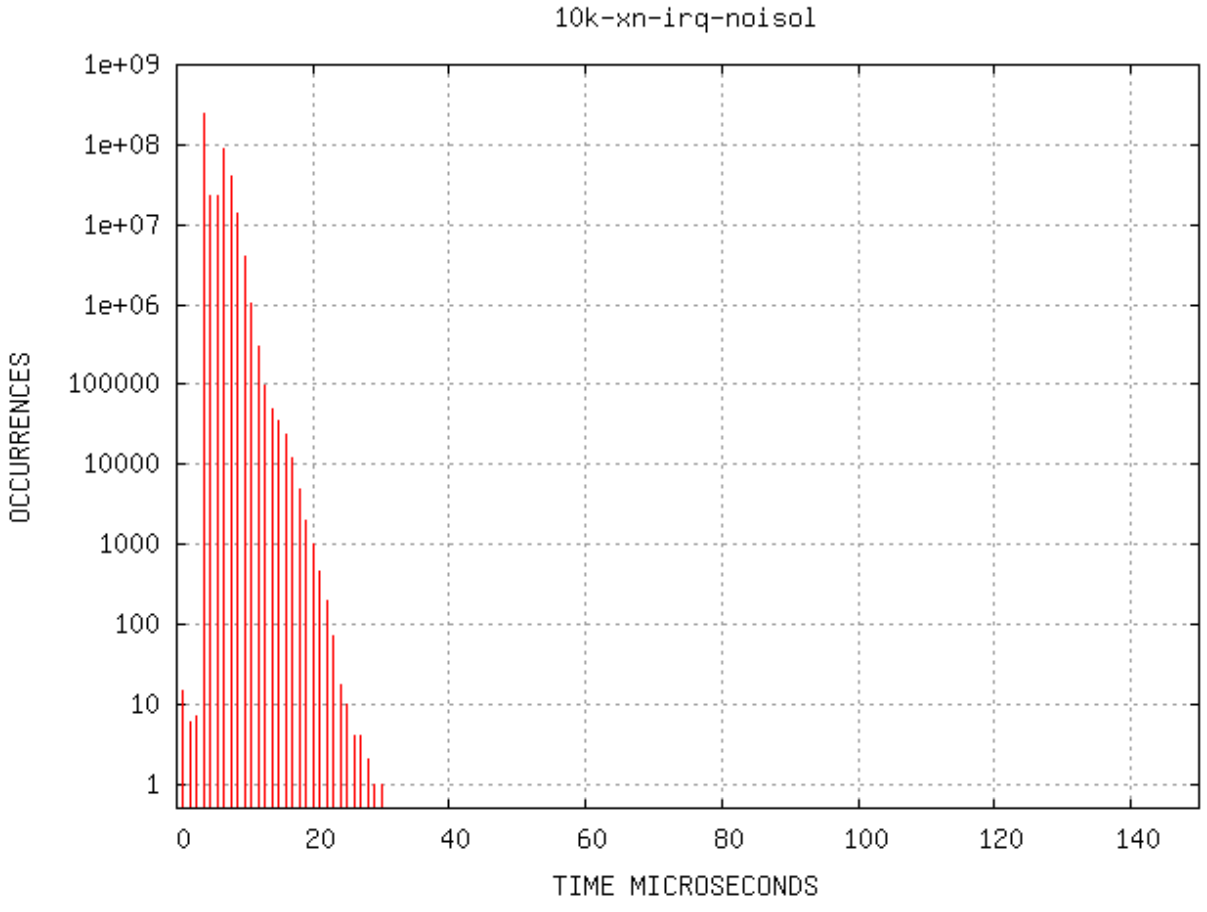
Latency: Kernel - Xenomai



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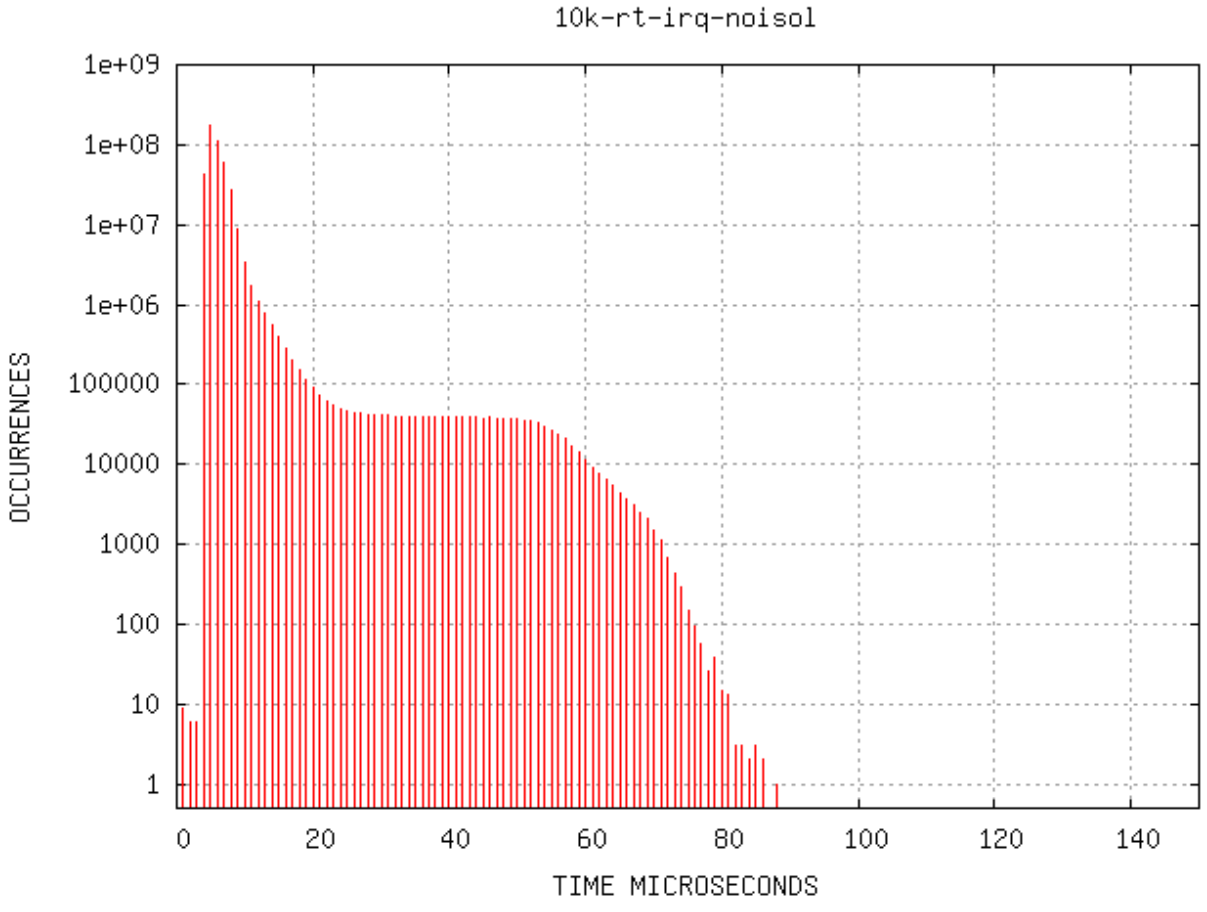
Latency: Kernel - Preempt RT



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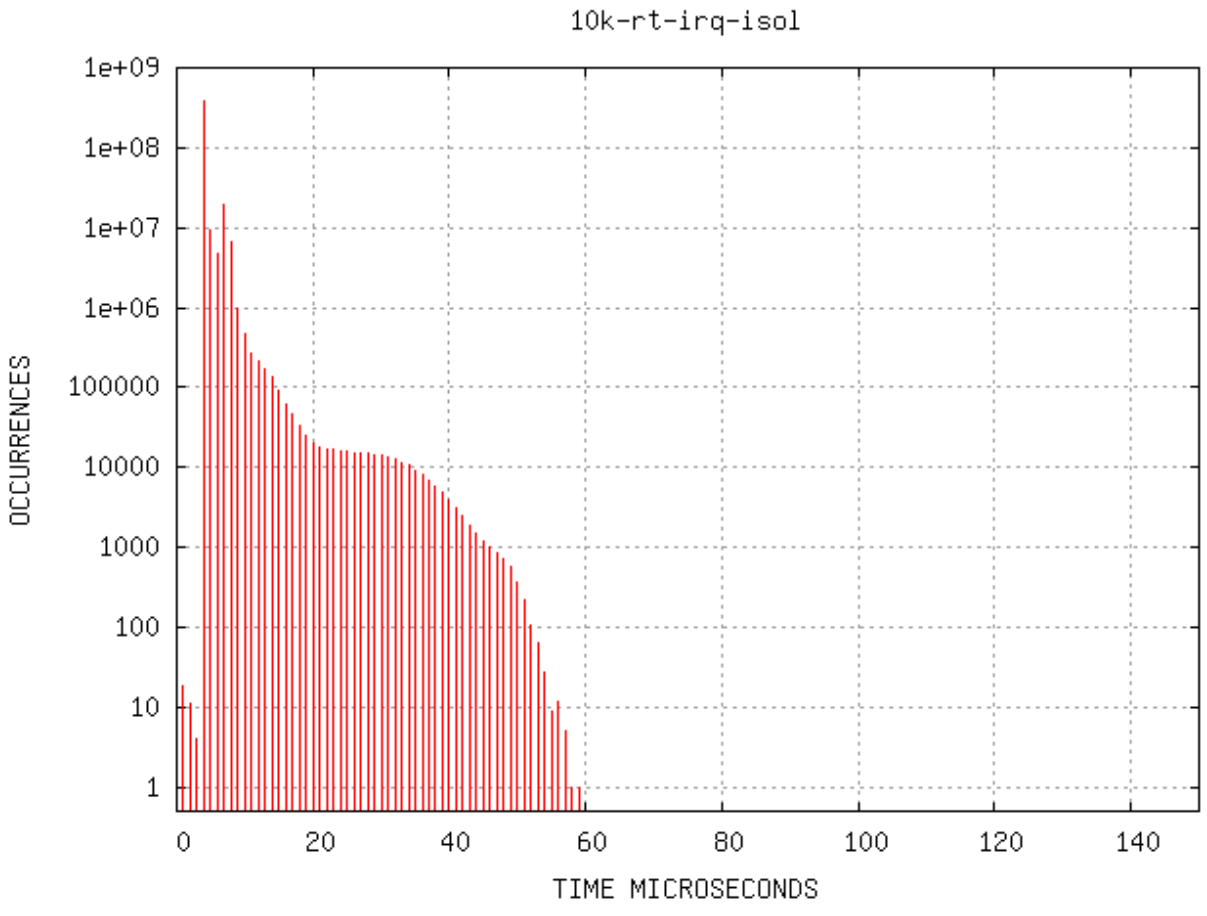
Latency: Kernel - Preempt RT (isolated CPU)



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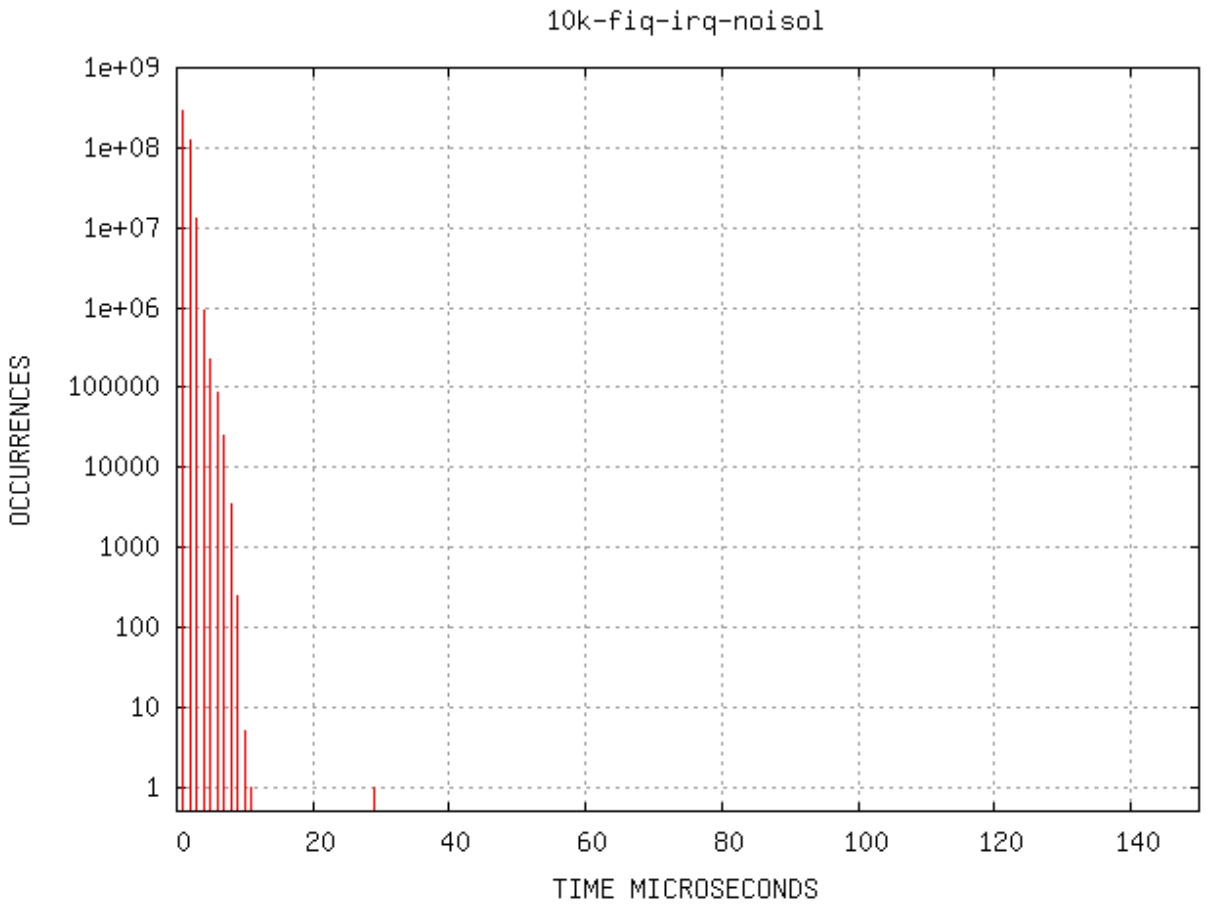
Latency: Kernel - Preempt RT with FIQ (fast interrupt)



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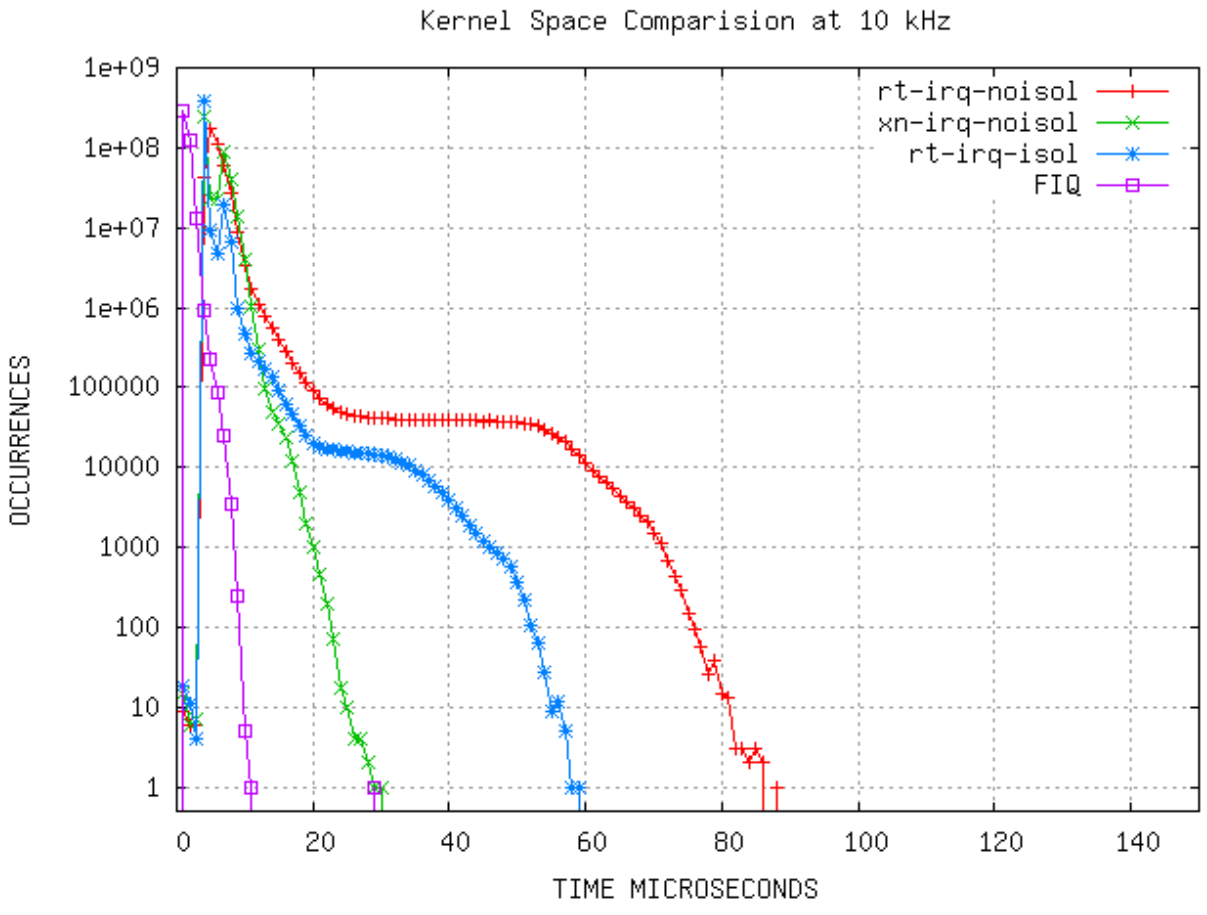
Latency: Kernel - Comparison



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Conclusion

- Microkernels are hard to handle
- For the most common use-cases the Microkernels do NOT have better latencies
- Simple usage of Preempt RT
- Preempt RT became the de-facto standard for Realtime Linux
- Integration of Preempt RT in Mainline Linux
- Real Time Linux collaborative project

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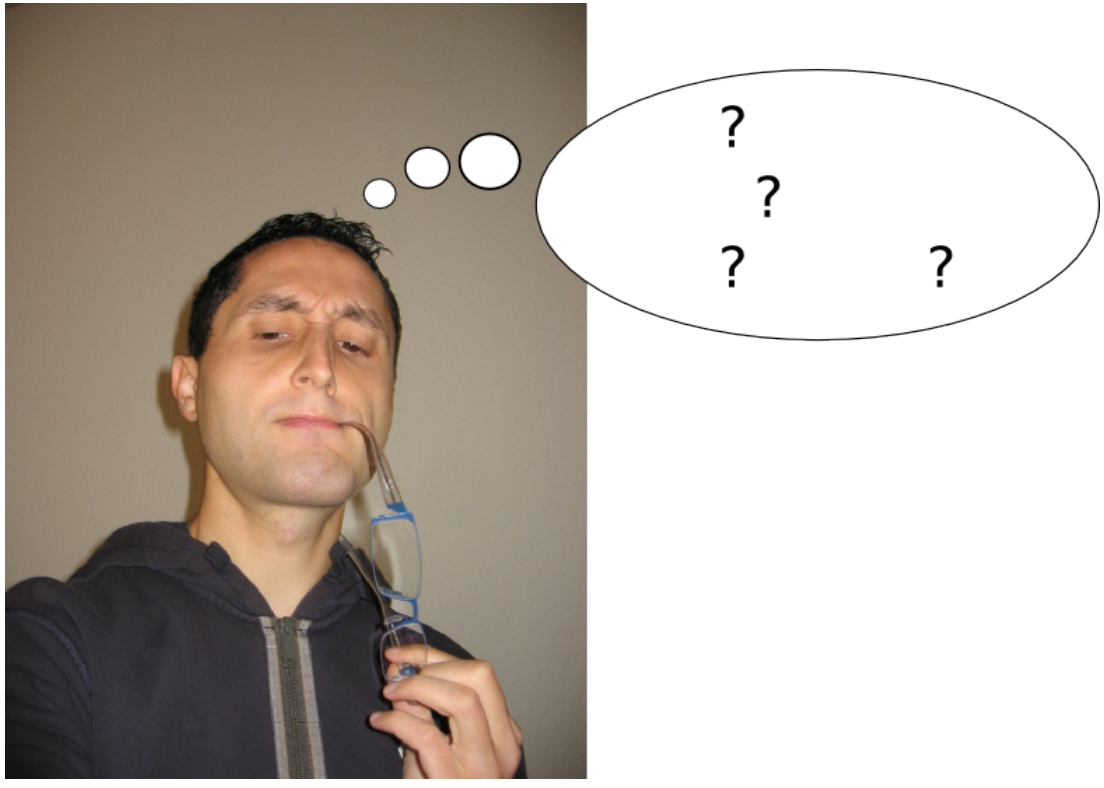
Questions?



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