

Realtime Linux uncovered

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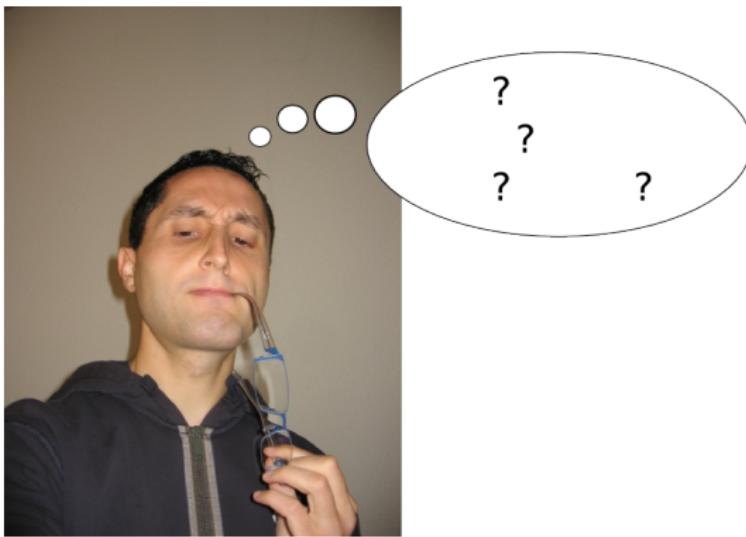
Overview

- 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?



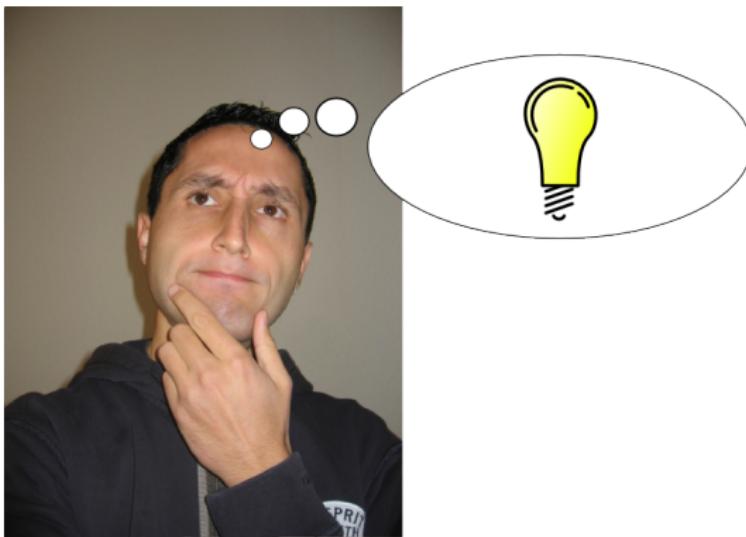
What is Realtime?

Performance?



What is Realtime?

It's all about DETERMINISM!



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:



What about "Softrealtime"?

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



Who is using it?

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

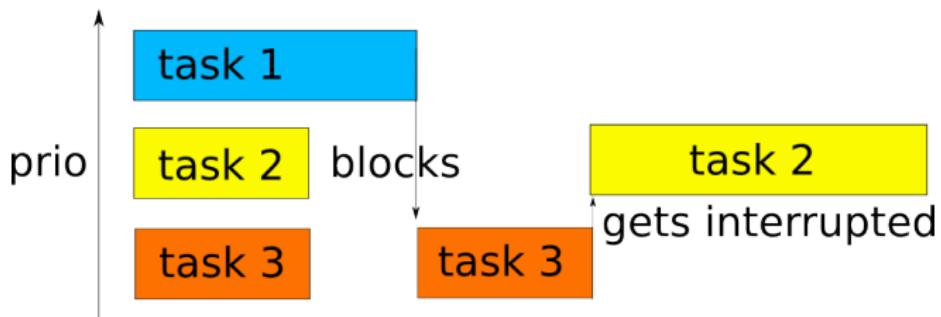


Requirements

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



Priority Inversion

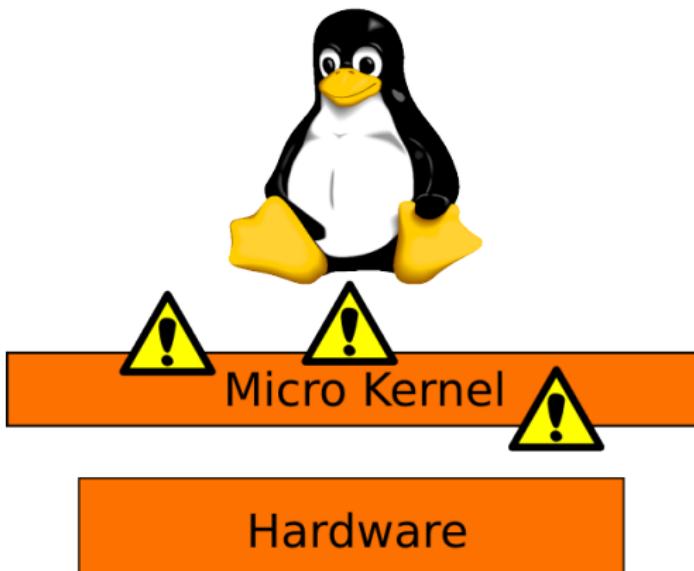


Approaches

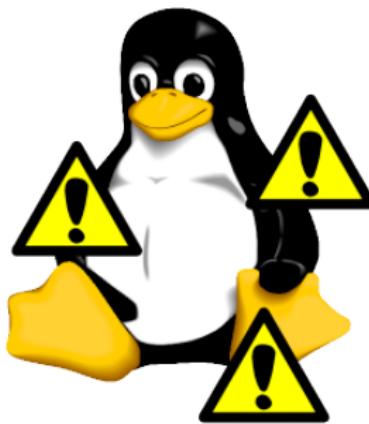
- ❑ Dual-Kernel
- ❑ In-Kernel / Single Kernel



Dual-Kernel



Single-Kernel



Hardware

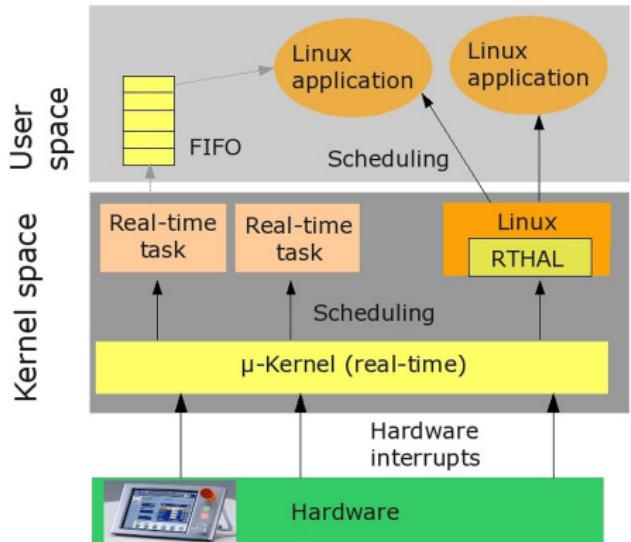


RTAI

- ❑ 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



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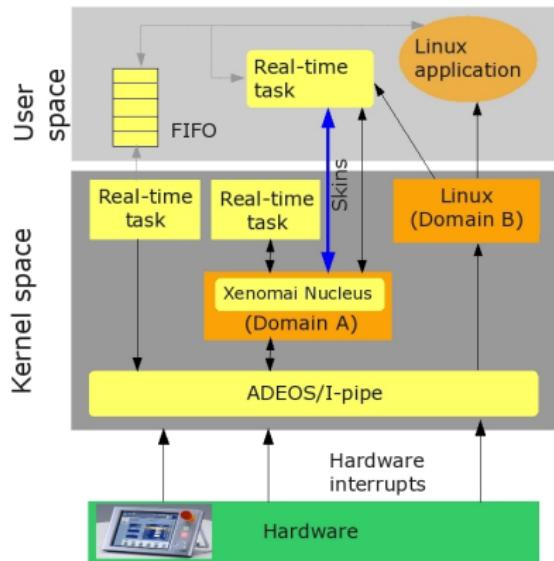


Xenomai

- ❑ 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



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
[...]
```

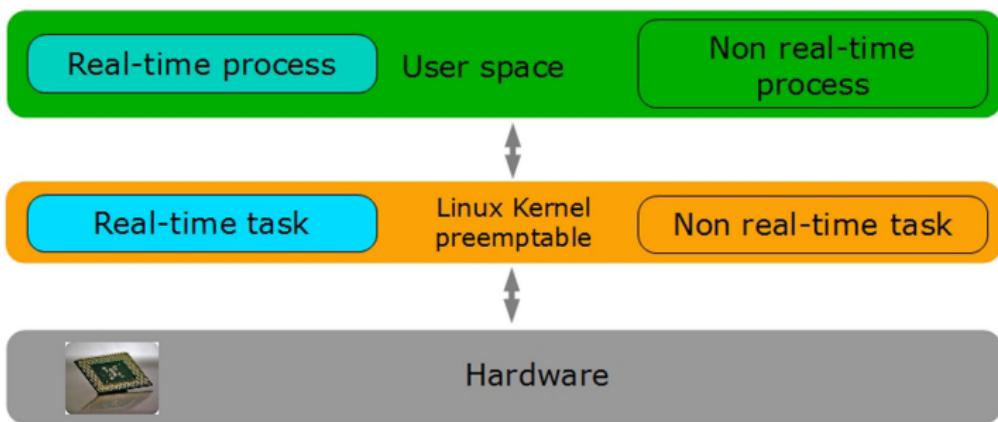


So, how does userspace deal with it?

- ❑ 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>

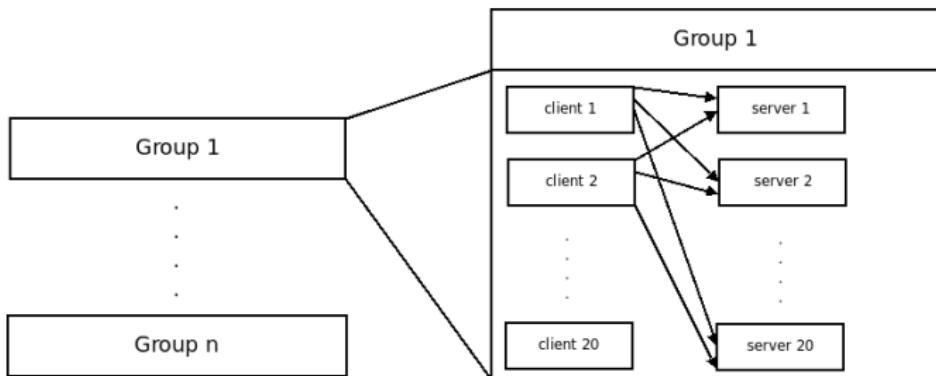


Latency Measurements on a Cortex A9 platform

- ❑ 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



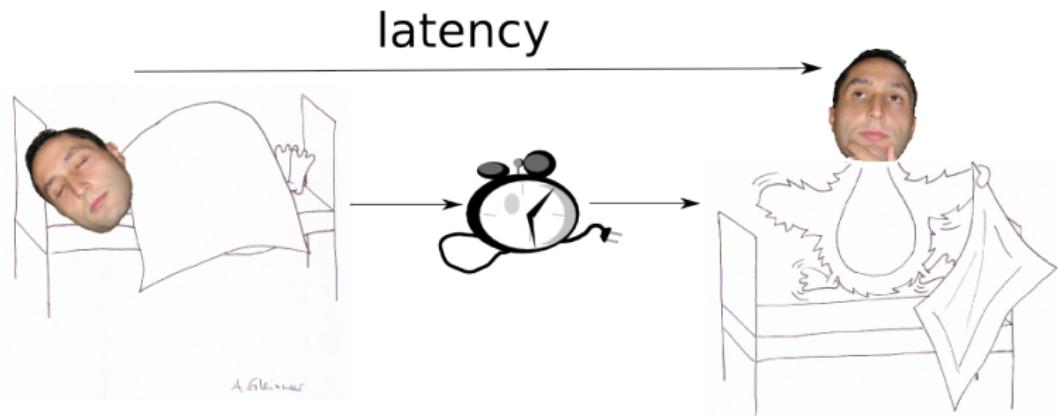
Load scenario: hackbench



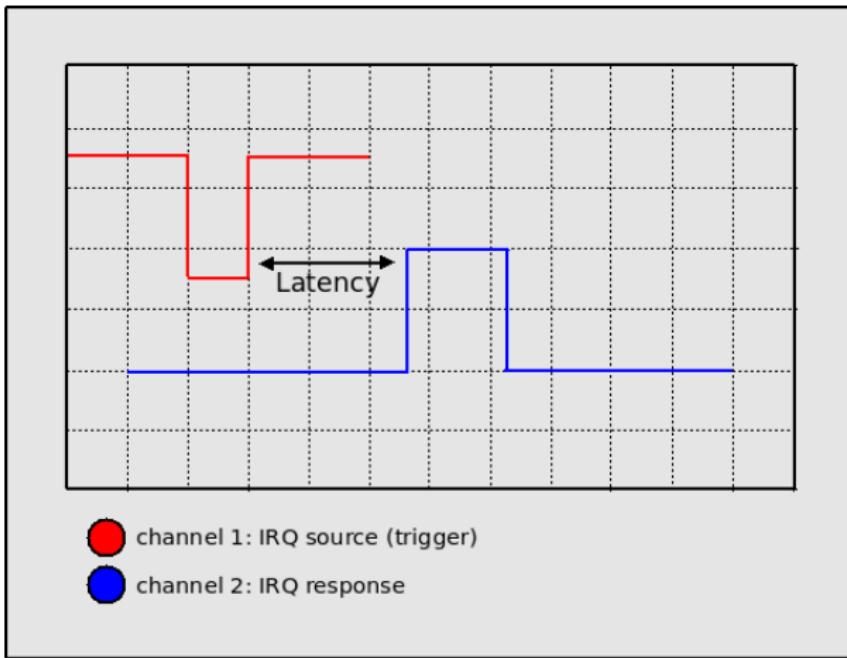
- ❑ Starts n groups of 20 clients and 20 servers
- ❑ Each client sends 100 messages to each server via a socket connection

What has been measured?

Latency and Jitter



Latency measurement

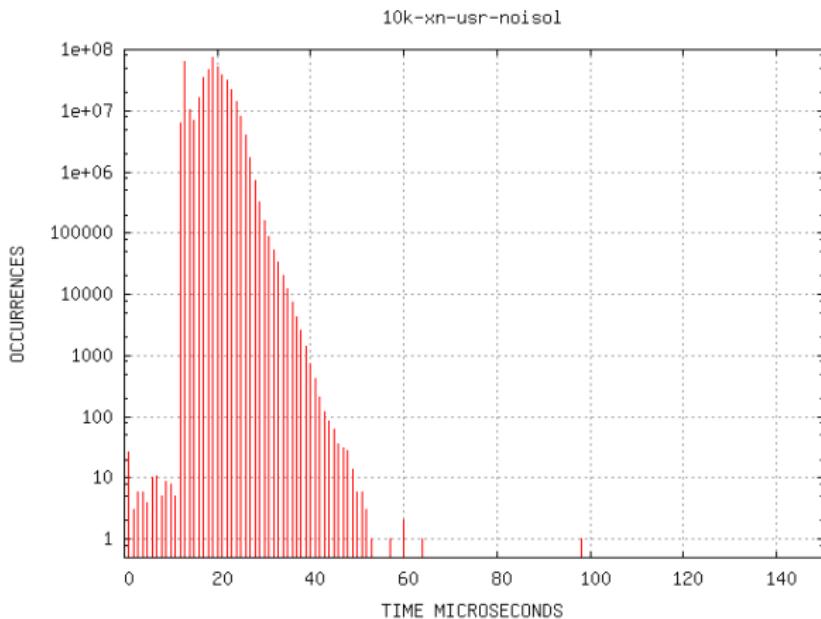


Userspace Latency: The most important usecase

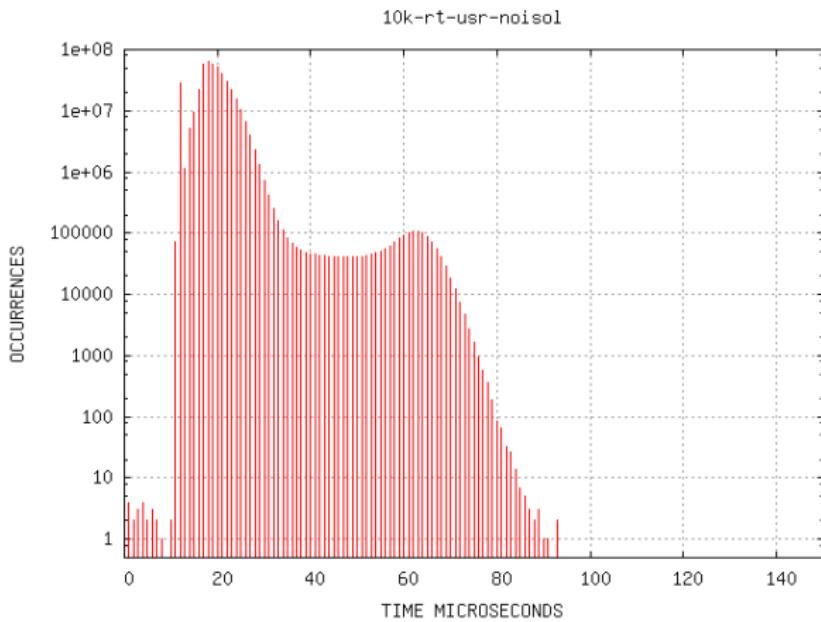
The most important usecase is the latency of a userspace task. Usually a userspace task needs to be synced with an external event.



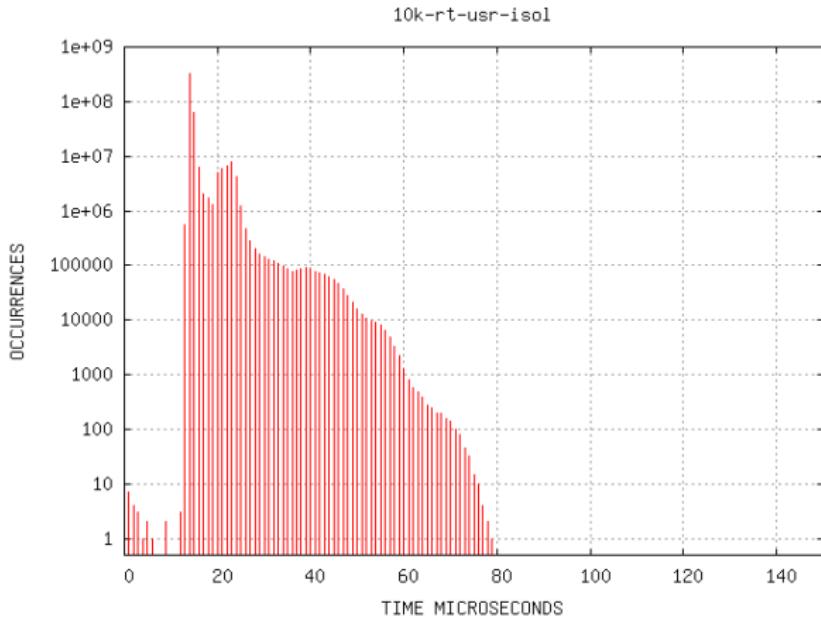
Xenomai: latency userspace task



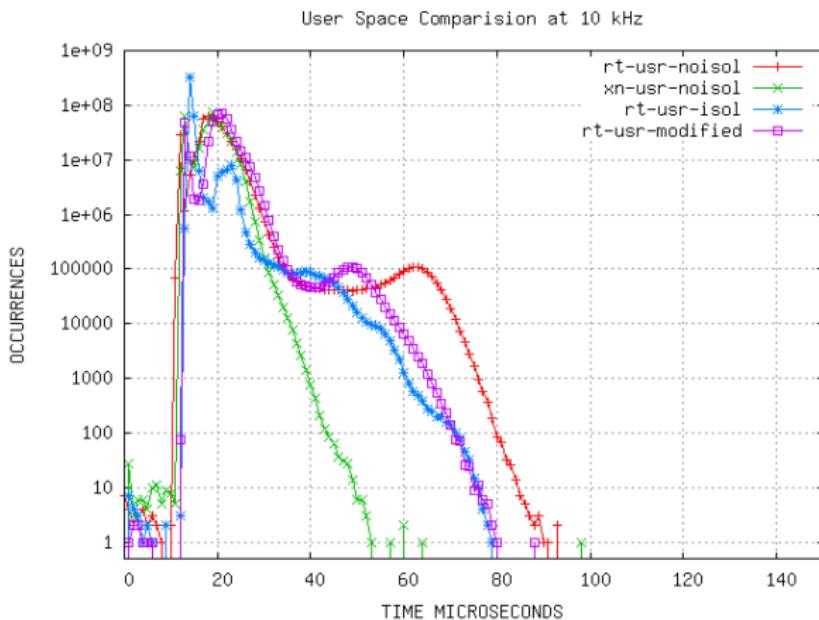
Preempt RT: latency userspace task



Preempt RT: latency userspace task (isolated CPU)



Latency userspace task - comparison



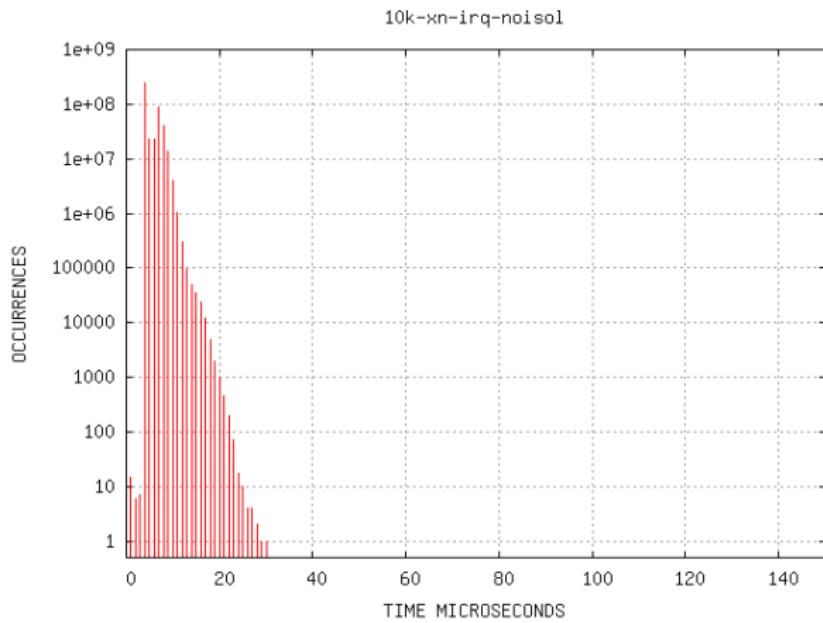
Latency within the Kernel



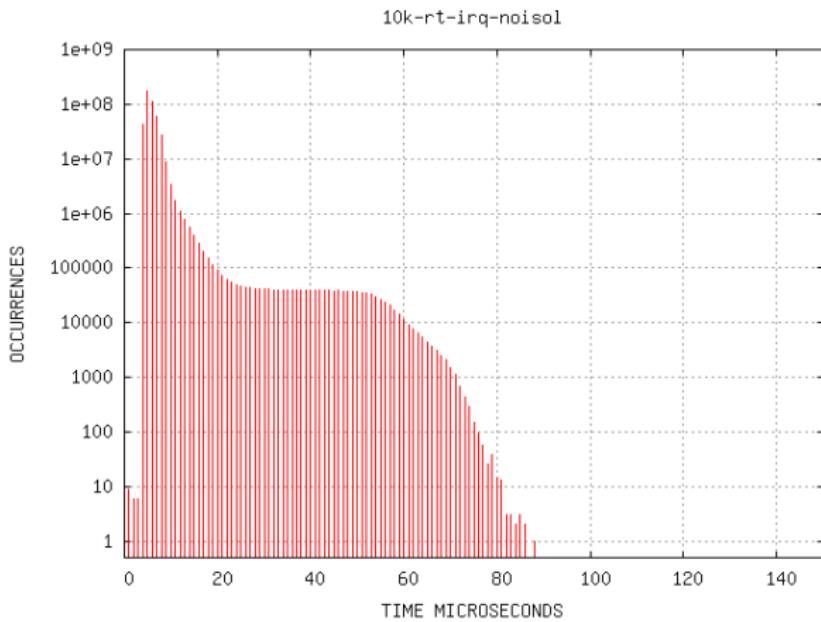
...or how to compare apples with pears!! ;-)



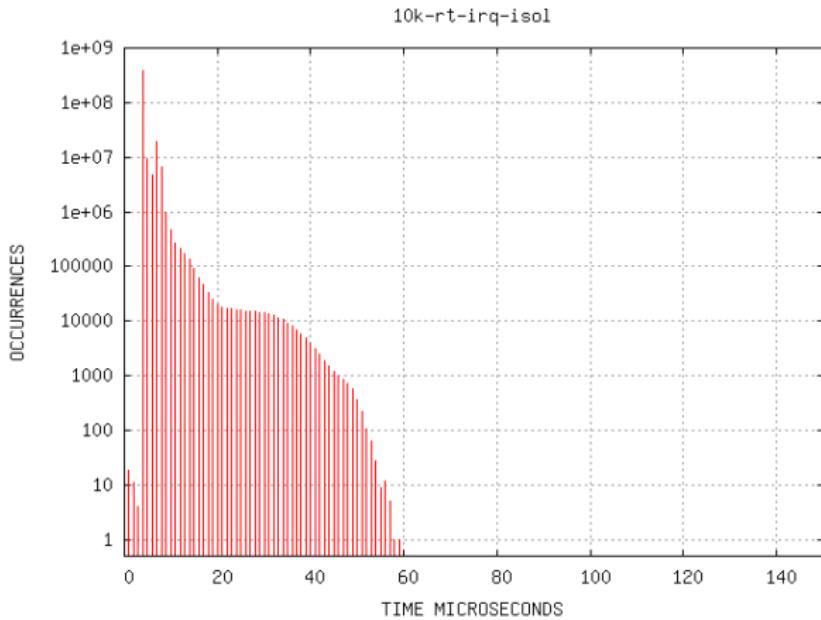
Latency: Kernel - Xenomai



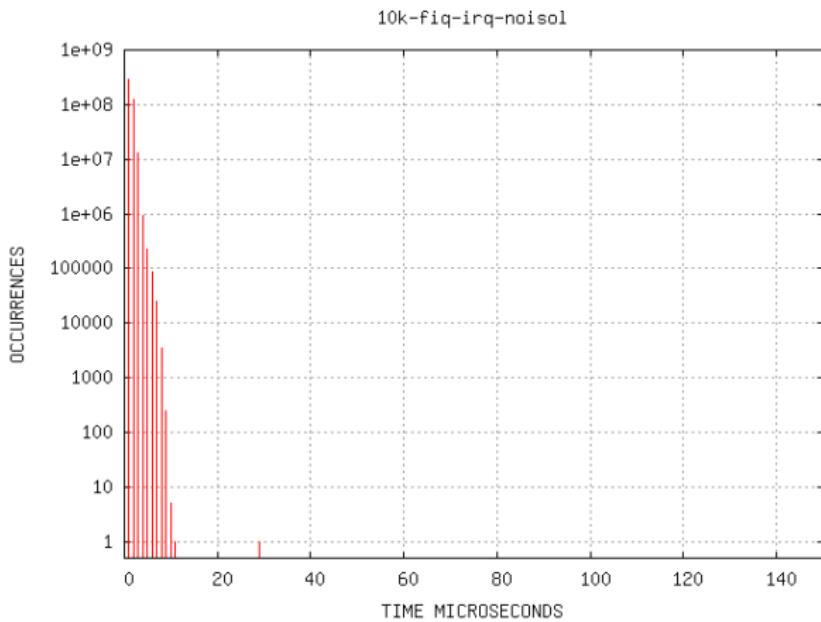
Latency: Kernel - Preempt RT



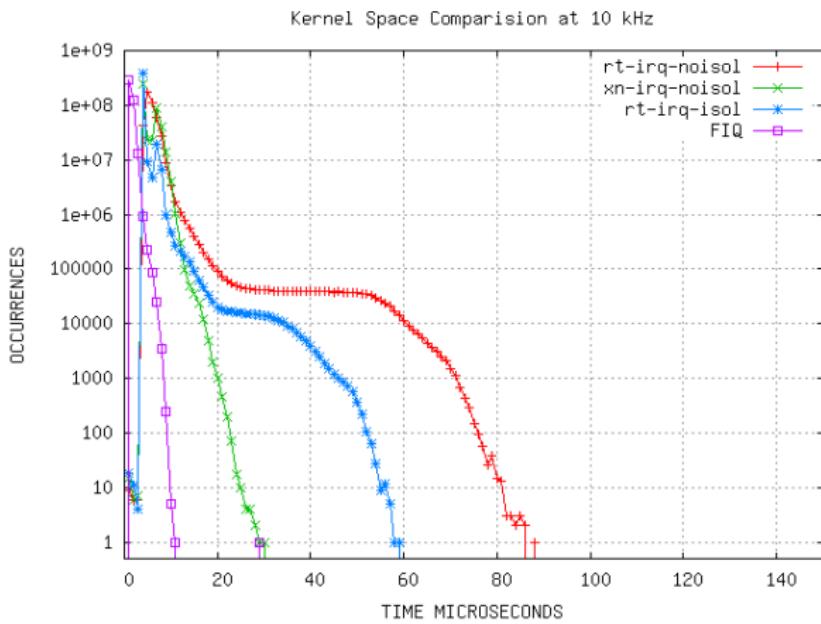
Latency: Kernel - Preempt RT (isolated CPU)



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



Latency: Kernel - Comparison



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



Questions?

