

Realtime Linux uncovered

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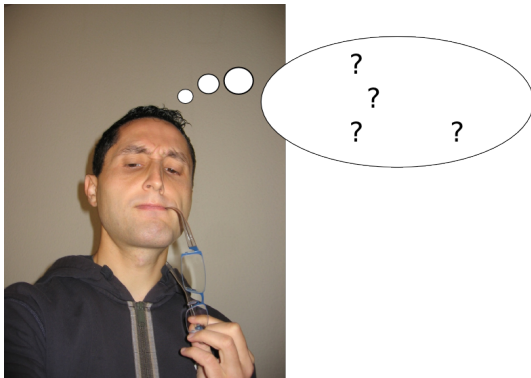
Overview

- 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?



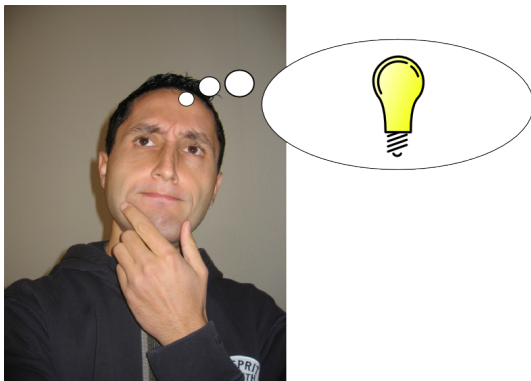
What is Realtime?

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 PLEEEAASSEEE forget about this word!!! :)



Who is using it?

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

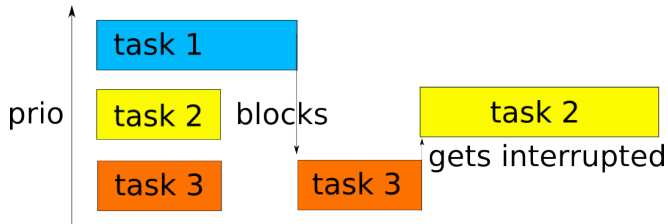


Requirements

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



Priority Inversion

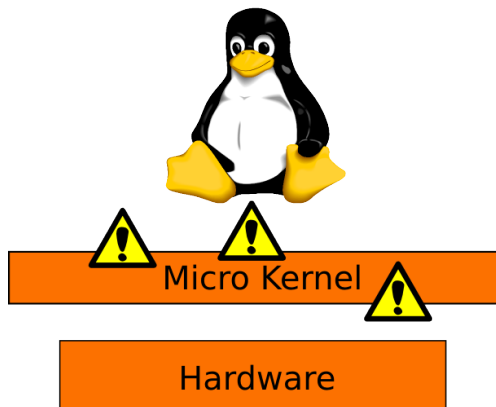


Approaches

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



Dual-Kernel



Single-Kernel



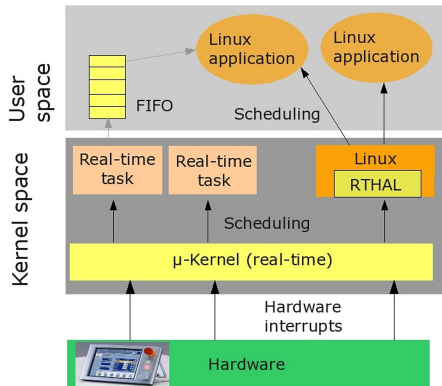
Hardware

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



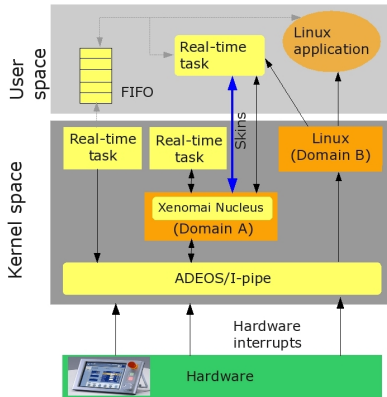
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Xenomai

- ❏ **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
-----	------	-----	---	---	---	---	---	-----	-----	---------	---------------

```
[...]
```

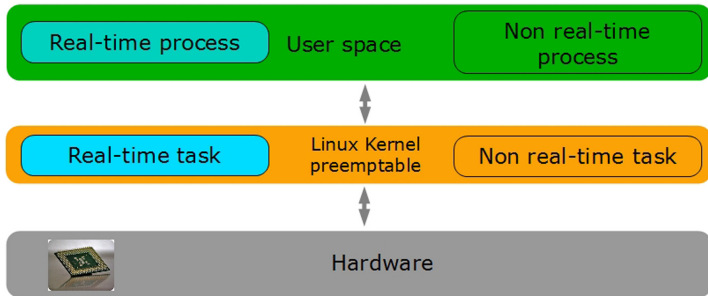


So, how does userspace deal with it?

- ❑ 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>

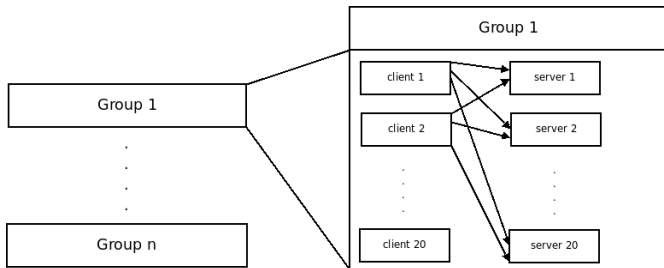


Latency Measurements on a Cortex A9 platform

- ❑ **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**



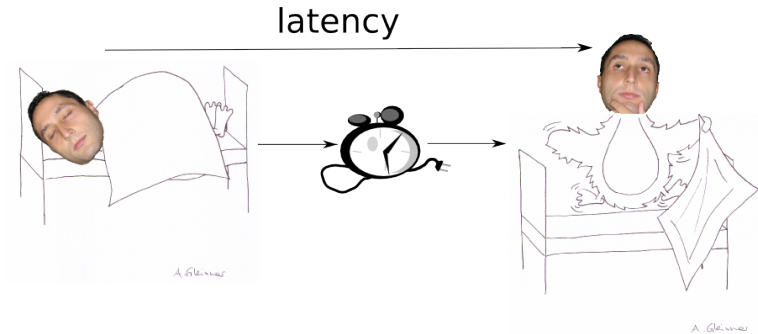
Load scenario: hackbench



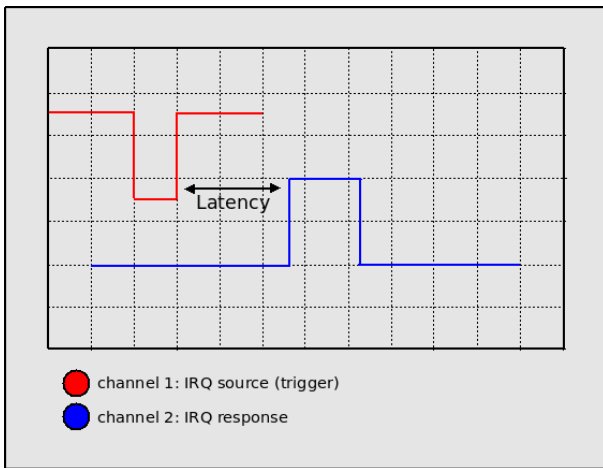
- 📦 Starts n groups of 20 clients and 20 servers
- 📦 Each client sends 100 messages to each server via a socket connection

What has been measured?

Latency and Jitter



Latency measurement

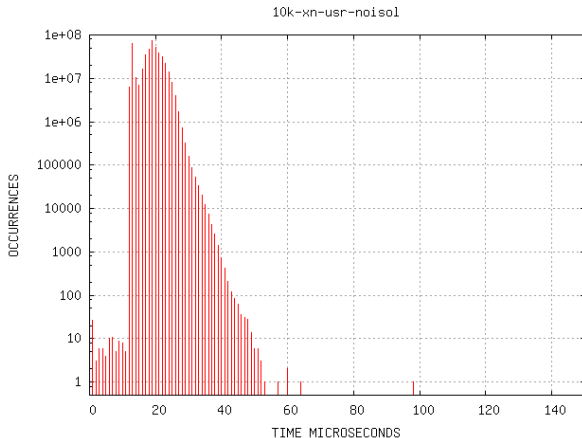


Userspace Latency: The most important usecase

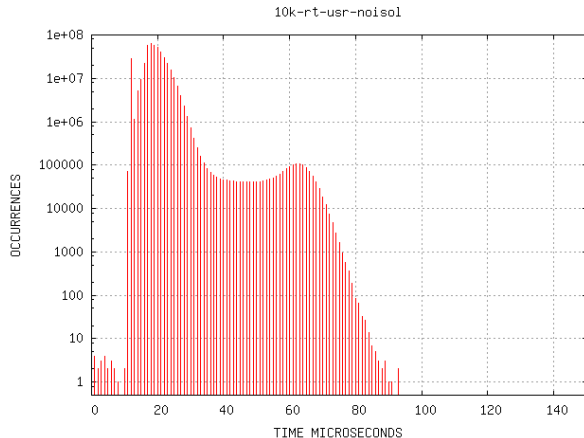
The most important usecase is the latency of a userspace task. Usually a userspace task needs to be synced with an external event.



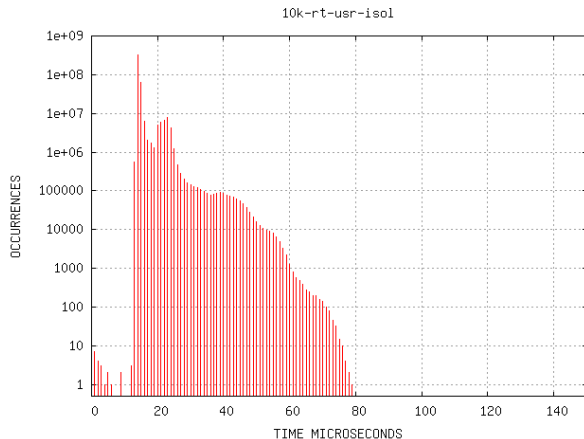
Xenomai: latency userspace task



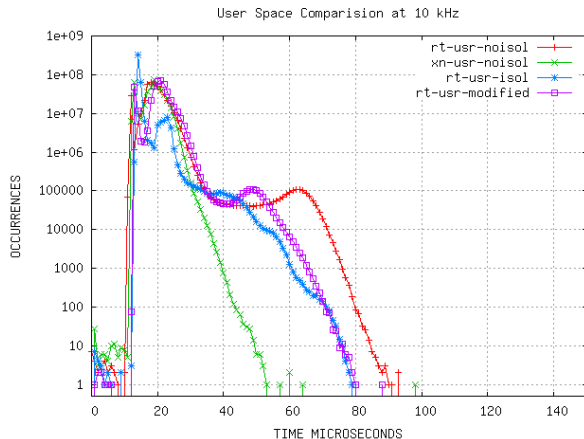
Preempt RT: latency userspace task



Preempt RT: latency userspace task (isolated CPU)



Latency userspace task - comparison

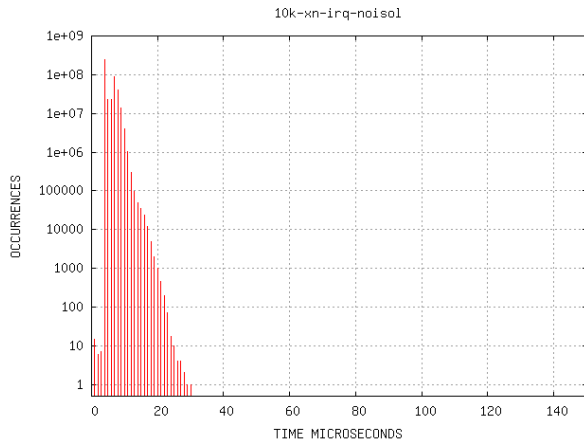


Latency within the Kernel

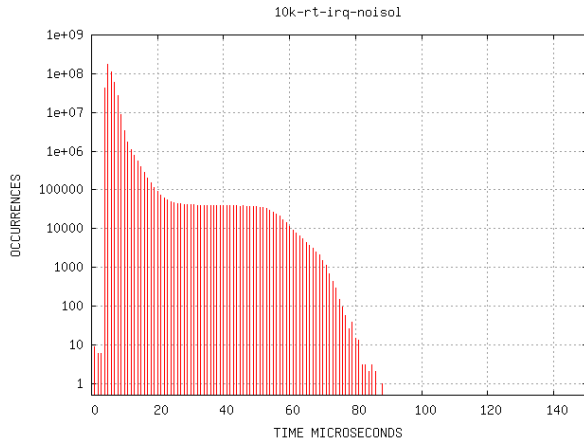


...or how to compare apples with pears!! ;-)

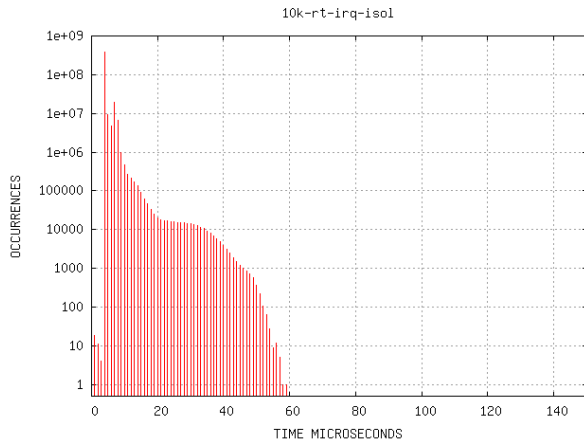
Latency: Kernel - Xenomai



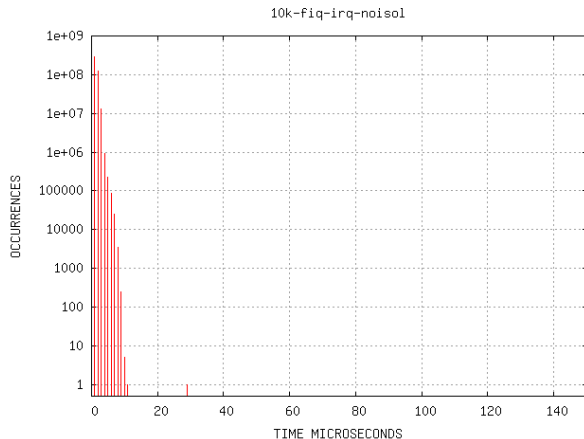
Latency: Kernel - Preempt RT



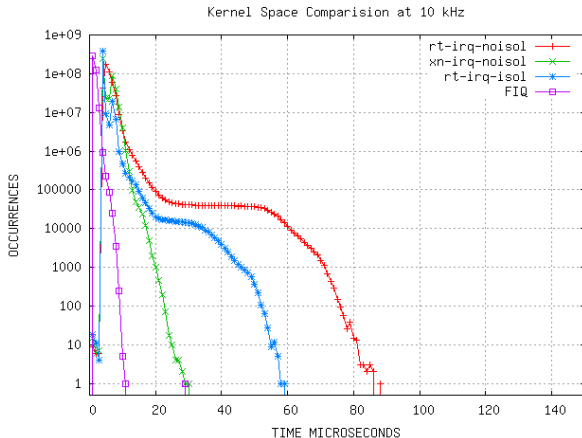
Latency: Kernel - Preempt RT (isolated CPU)



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?

