Introduction to Realtime Linux

Jan Altenberg

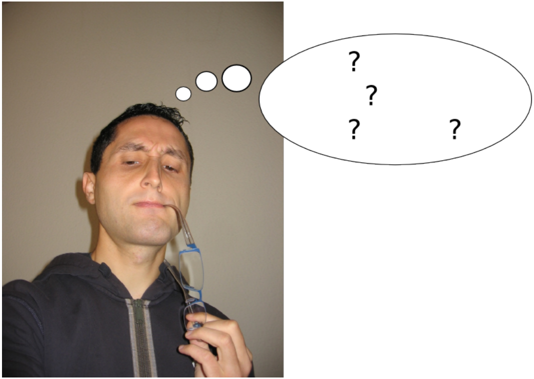
Linutronix GmbH

Overview

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

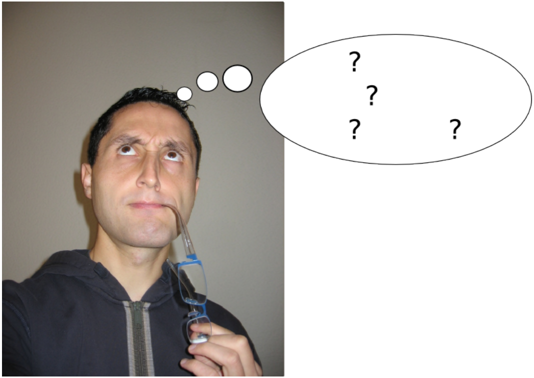
What is Realtime?

Fast execution time?



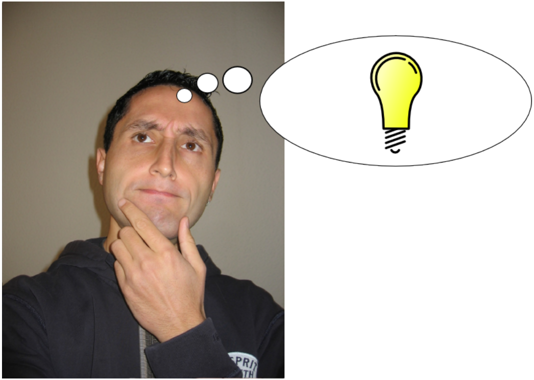
What is Realtime?

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

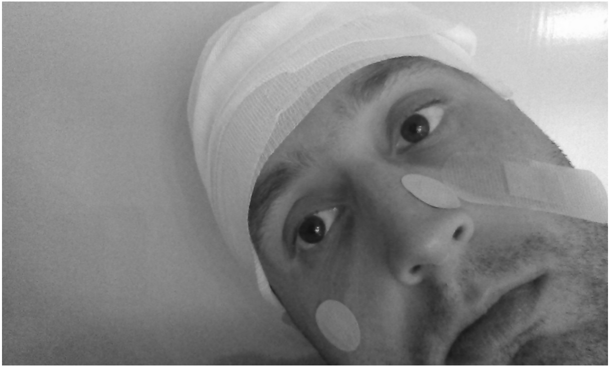
Remember!

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 PLEEAAASSEEE forget about this word!!! :)

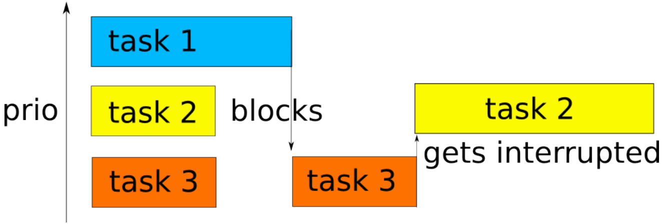
Who is using it?

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

Requirements

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

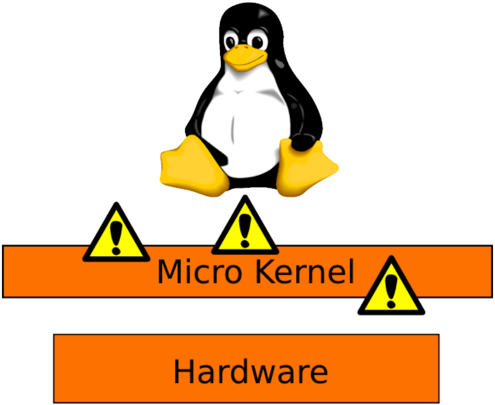
Priority Inversion



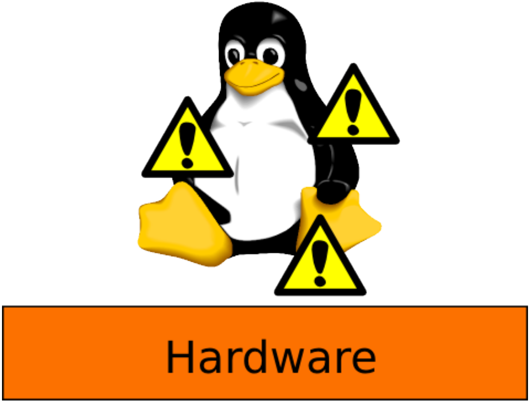
Approaches

- Dual-Kernel
- In-Kernel / Single Kernel

Dual-Kernel



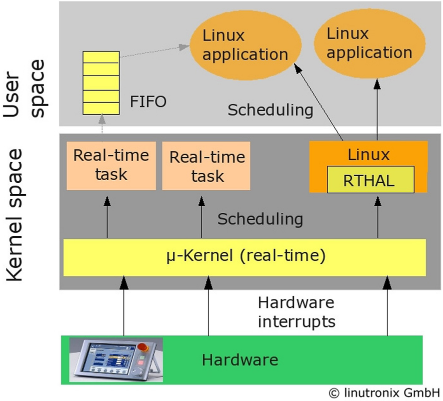
Single-Kernel



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

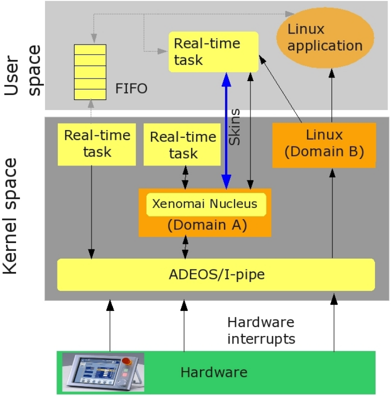
RTAI


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
© linutronix GmbH

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

Preempt RT

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

Preempt RT und 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

How Preempt RT brings Realtime to Linux?

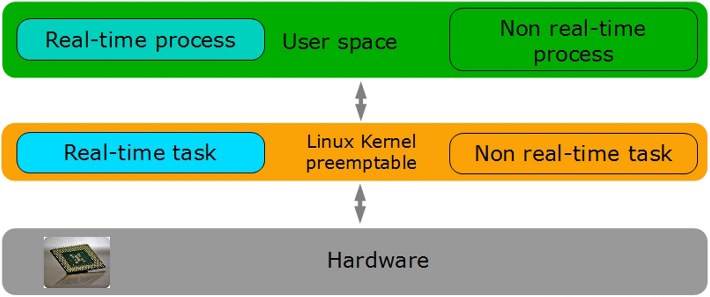
Remember once again...

Preemption is the most important requirement for a Realtime System

How Preempt RT brings Realtime to Linux?

- Locking Primitives: Spinlocks are replaced by RT Mutexes. Raw Spinlocks behave like the original Spinlocks.
- Interrupt Handlers run in a kernel thread

Preempt RT

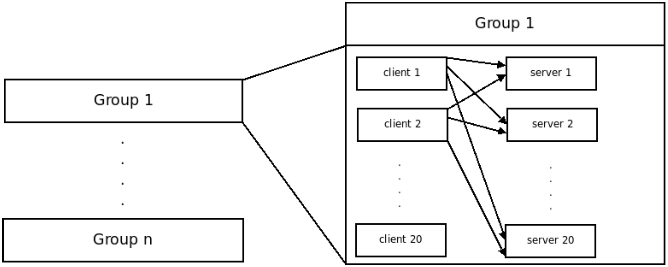


© linutronix GmbH

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

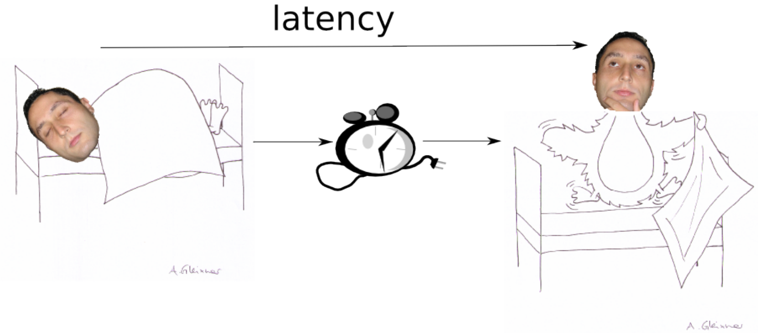
Load scenario: hackbench



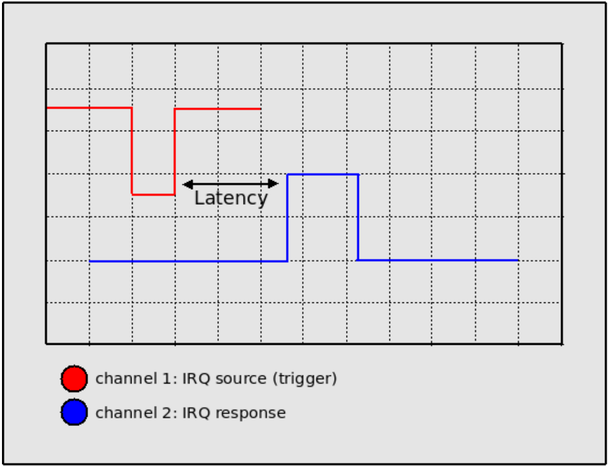
- Starts n groups of 20 clients and 20 servers
- Each client sends 100 messages to each server via a socket connection

What has been measured?

Latency and Jitter



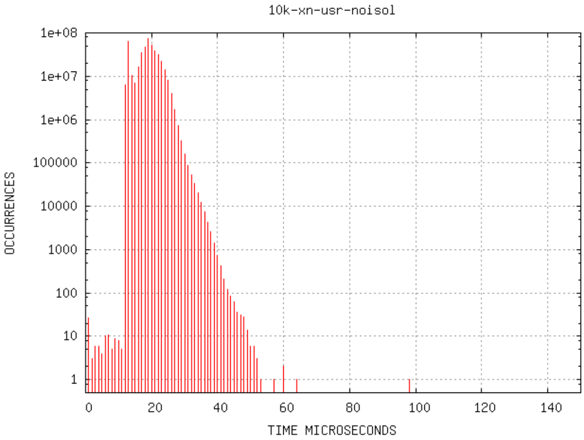
Latency measurement



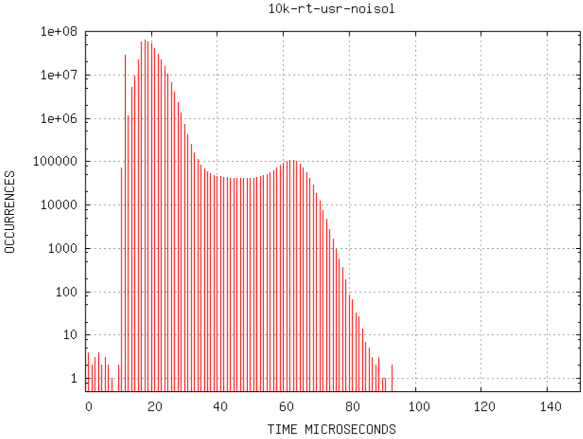
Userspace Latency: The most important usecase

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

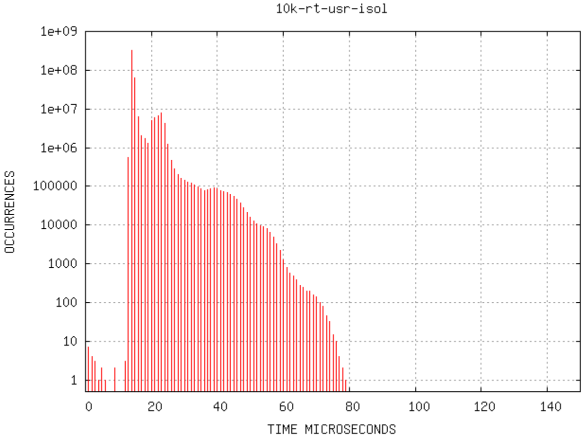
Xenomai: latency userspace task



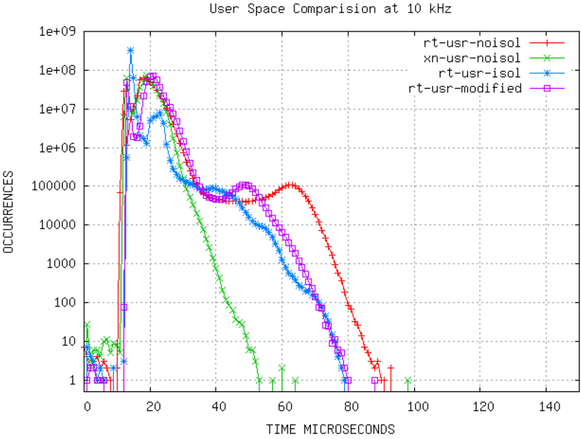
PREEMPT_RT: latency userspace task



PREEMPT_RT: latency userspace task (isolated CPU)



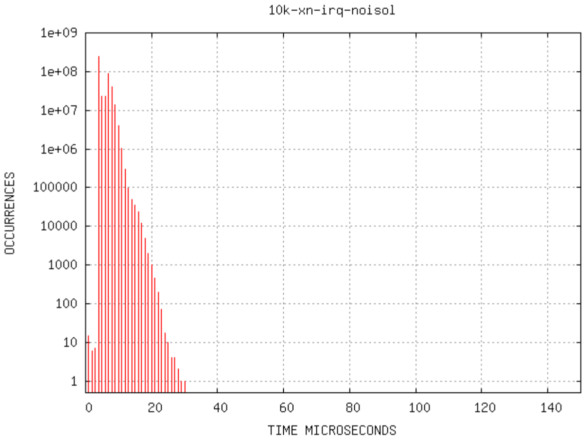
Latency userspace task - comparison



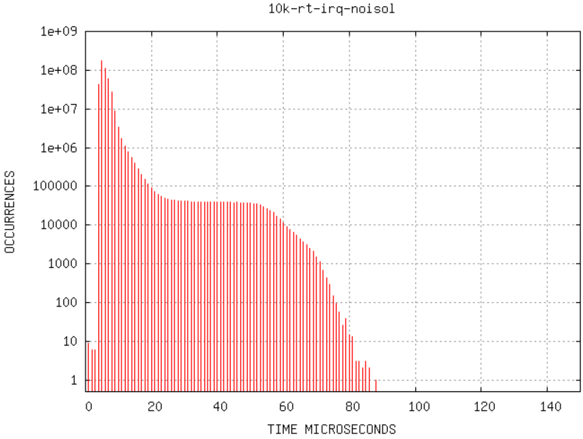
Latency within the Kernel

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

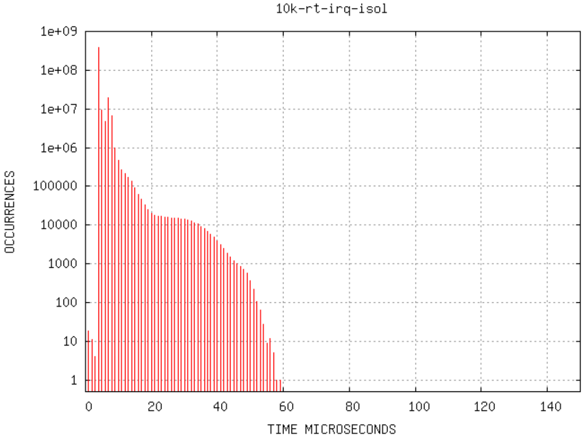
Latency: Kernel - Xenomai



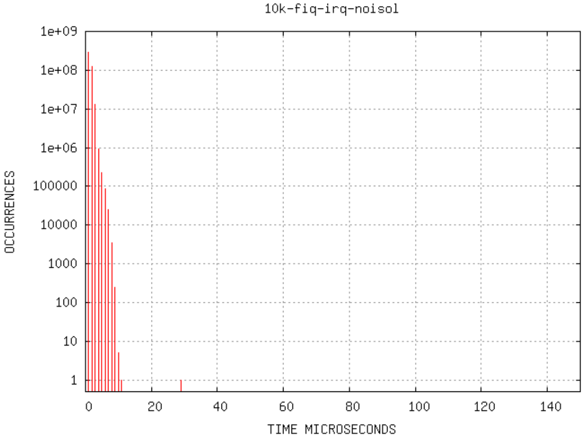
Latency: Kernel - PREEMPT_RT



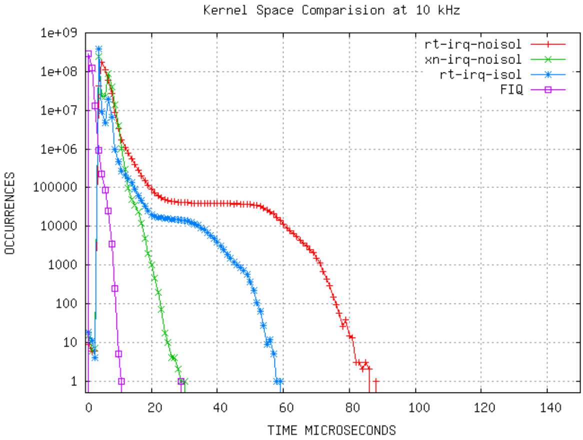
Latency: Kernel - PREEMPT_RT (isolated CPU)



Latency: Kernel - PREEMPT_RT with FIQ (fast interrupt)



Latency: Kernel - Comparison



Conclusion

- PREEMPT_RT became the de-facto standard for Realtime Linux
- Integration of PREEMPT_RT in Mainline Linux
- Simple usage of PREEMPT_RT
- Microkernels are hard to handle
- For the most common use-cases the Microkernels do NOT have better latencies
- FIQs offer fast latencies, but are hard to handle

Questions?