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San Francisco 2017

Understanding Real Time Linux

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Agenda

- What's real time OS
- RTL project status
- RT testing and tracing
- Reasons of latency and solutions for them
- Resources
- Summary

What's real time OS

- Real time and high performance
  - Fastest? Max throughput? Average latency?
  - No, predictable latency!
- Types:
  - Hard real time
    - Car engine, Nuclear power plant
  - Firm real time
    - Between hard/soft
  - Soft real time
    - Live audio/video
- RTOS list link

RTL project status

- RTL project
  - Linux Foundation plan to merge all RT code into upstream
  - Main team member of RT: Thomas Gleixner, Sebastian Siewior, Richard Cohran, Anna-Maria Gleixner, Benedikt Spranger
  - David Long, Mathieu Poirier and Alex also work on it.
- Much of code merged into upstream
  - High res timer
  - Threaded interrupt
  - Lock dep / Ftrace
- A few code out of kernel
  - 400+ patches, < 20,000 lines
  - Sleep locking
  - Interrupt preemptable -- transfer to local lock
  - Optimized for Cpu hotplug Timers; memory alloc; Softirq; Rcu

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RT testing and tracing

- Kernel setting
  - # CONFIG_PREEMPT_NONE
  - # CONFIG_PREEMPT_VOLUNTARY
  - # CONFIG_PREEMPT__LL
  - # CONFIG_PREEMPT_RTB
  - CONFIG_PREEMPT_RT_FULL=y
- Testing
  - Benchmarks: rt-tests, rt-app, ltp-realtime
  - ./cyclitest --smp -p98 -m
  - System stress: hackbench -l 10000
  - Results on my hikey620 and dragonaboard 410
    - Maximum latency less than 200 us in a busy system
- Tracing
  - Function trace
  - Latency trace

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Latency tracing

```
# echo 0 > options/function-trace; echo wakeup_rt > current_tracer; echo 1 > tracing_on; chrt -f 5 sleep 1; echo 0 > tracing_on
# cat trace
# tracer: wakeup_rt
#
# wakeup_rt latency trace v1.1.5 on 4.11.12-rt13
# --------------------------------------------------------------------
# latency: 786 us, #4/4, CPU#5 | (M:preempt VP:0, KP:0, SP:0 HP:0 #P:8)
#    -----------------
#    | task: irq/38-f72c0000-1321 (uid:0 nice:0 policy:1 rt_prio:50)
#    -----------------
#
#                  _--------=> CPU#
#                 / _-------=> irqs-off
#                | / _------=> need-resched
#                || / _-----=> need-resched_lazy
#                ||| / _----=> hardirq/softirq
#                |||| / _---=> preempt-depth
#                ||||| / _--=> preempt-lazy-depth
#                |||||| / _-=> migrate-disable
#                ||||||| /     delay
# cmd     pid    |||||||| time   |  caller
#    \   /       ||||||||   \    |  /
  <idle>-0       0d..h4..    1us :      0:120:R   + [005]  1321: 49:R irq/38-f72c0000
  <idle>-0       0d..h4..    3us!: try_to_wake_up <-wake_up_process
  <idle>-0       5d...3..  780us : __schedule <-schedule
  <idle>-0       5d...3..  784us :      0:120:R ==> [005]  1321: 49:R irq/38-f72c0000
```

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Reasons/Solutions of latencies

- CPU Capacity and System load
- Memory
- Devices
- Interrupt
- Schedule
- Firmware/BIOS routines
- Power management side effect
- SMP sync up

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Reasons/Solutions of latencies

- CPU Capacity and System load
  - 1 Ghz CPU freq required*
  - Busy system load
- Way to make real time friendly ENV
  - Isolated cpu
  - Dedicated resource for RT tasks
  - System tuning
    - Documentation/kernel-per-CPU-kthreads.txt
    - Taskset etc
    - isolcpus=

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Reasons/Solutions of latencies

- Memory
  - Page fault/reclaim cost a lots
  - Swap cause disk level response time
  - Fragment issue for larger memory allocation
- Workaround
  - Pre-allocate memory
  - Use slub for defragmentation
  - Reduce the page alloc locking region

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Reasons/Solutions of latencies

- Devices/interrupt
  - DMA may holding bus for long time
  - Interrupt:
    - time cost to trap into kernel and stay long
    - break the RT task;
    - Interrupt disable region -- irq_save
- solutions
  - threaded interrupt,
    - Prioritize
    - preemptable
  - Irq disable -> local spin lock.

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Reasons/Solutions of latencies

- Firmware/BIOS
  - Some device routine defined in firmware/bios
  - Secure system, Trust zone

- Power management cost
  - Cpu/clusters c-status, p-state -- use PM QoS or don’t use them
  - Thermal setting -- cooling system

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Reasons/Solutions of latencies

- Schedule cost
  - tlb/cache flush
  - Page table refill
  - System load
- Optimize
  - Priority tasks: FIFO, RR, deadline
  - Control normal task preempt
    - Preempt in spin_lock -- lazy preempt
  - Lazy mm replace
  - TLB/Cache flush range

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Reasons/Solutions of latencies

- SMP sync up
  - Spin_lock, rw_lock etc.
- Solution:
  - Sleepable/preemptable spin_lock/rwlock: rt_mutex
    - Migration disable
  - Rwlock: reader bias rwlock or use rcu instead.

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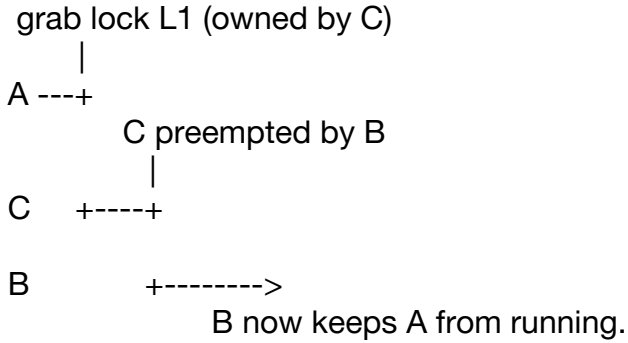
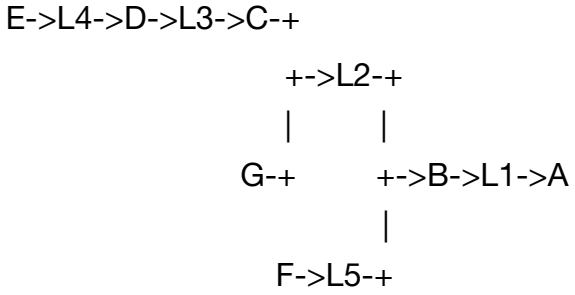
Priority inversion

- Priority of RT task
  - Necessary to preempt normal task



- Priority inversion
  - Priority inherit



Resource links

- RT tree
  - git://git.kernel.org/pub/scm/linux/kernel/git/rt/linux-rt-devel.git
- Real time wiki
  - https://wiki.linuxfoundation.org/realtime/start
  - https://rt.wiki.kernel.org/index.php/Main_Page
- RT mailing list
  - https://wiki.linuxfoundation.org/realtime/communication/mailinglists
- RT testing
  - https://git.linaro.org/power/rt-app.git
- IRC
  - #linux-rt on irc.oftc.net

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Summary

- RTL status
  - All upstream is on the way
- Kernel changes for latency
  - Sleepable spin_lock/rwlock
  - preemptable Irq_save
- Resources of RT
  - https://wiki.linuxfoundation.org/realtime/start

Thank You

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#SFO17

BUD17 keynotes and videos on: connect.linaro.org

For further information: www.linaro.org