Inside The RT Patch

Talk:

Steven Rostedt
(Red Hat)

Benchmarks:

Darren V Hart
(IBM)

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Understanding PREEMPT_RT

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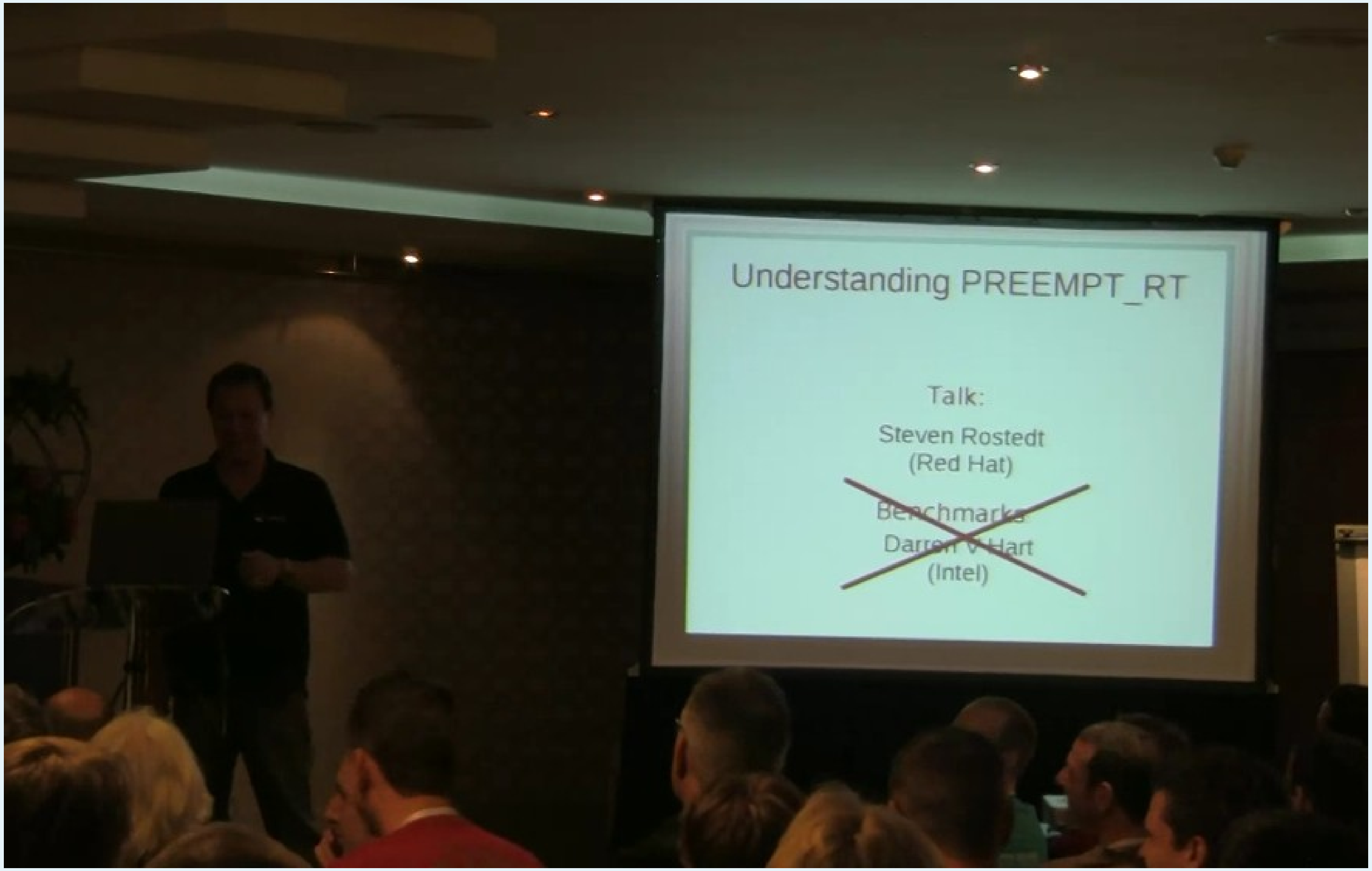
ELC-EU

- http://free-electrons.com/blog/elce-2012-videos/



So what should I talk about?

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Trebuchet

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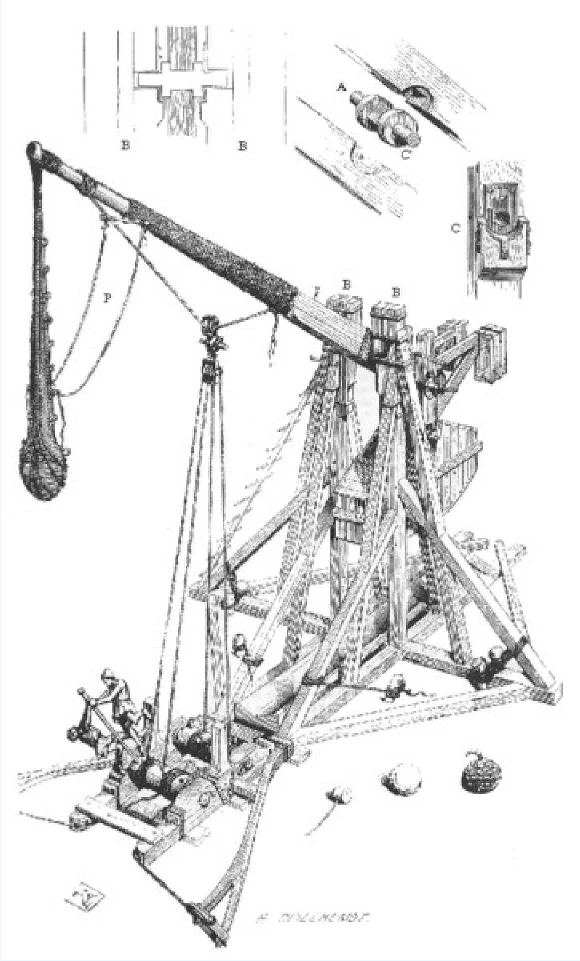

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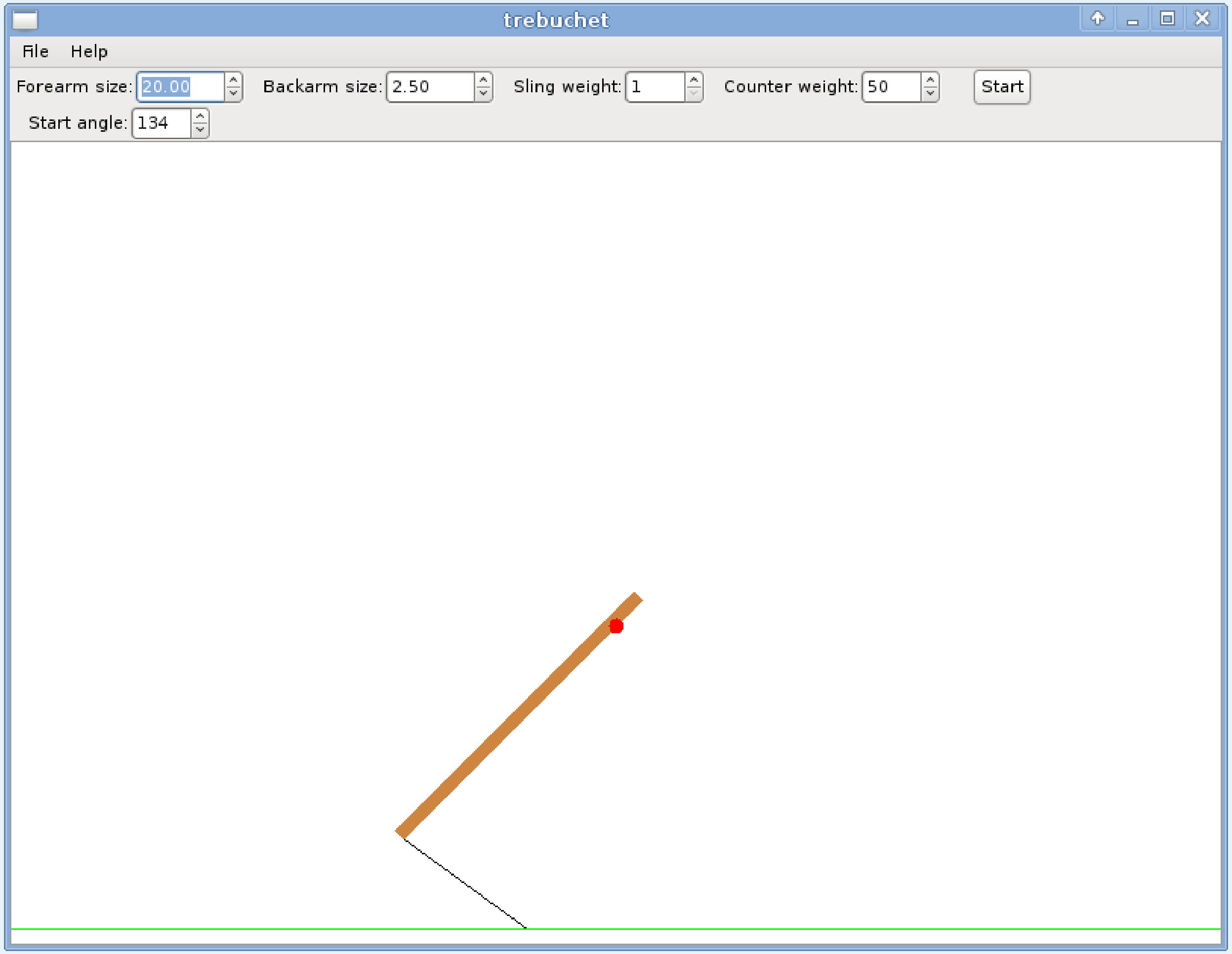
Trebuchet



trebuchet
File Help
Forearm size: 20.00
Backarm size: 2.50
Sling weight: 1
Counter weight: 50
Start
Start angle: 134

Trebuchet

$$
\begin{aligned}
L &= \text{Kinetic Energy} - \text{Potential Energy} \\
&= \frac{1}{2}m\left(v_1^2 + v_2^2\right) + \frac{1}{2}I\left(\dot{\theta}_1^2 + \dot{\theta}_2^2\right) - mg\left(y_1 + y_2\right) \\
&= \frac{1}{2}m\left(\dot{x}_1^2 + \dot{y}_1^2 + \dot{x}_2^2 + \dot{y}_2^2\right) + \frac{1}{2}I\left(\dot{\theta}_1^2 + \dot{\theta}_2^2\right) - mg\left(y_1 + y_2\right)
\end{aligned}
$$

$$
L = \frac{1}{6}m\ell^2\left[\dot{\theta}_2^2 + 4\dot{\theta}_1^2 + 3\dot{\theta}_1\dot{\theta}_2\cos(\theta_1 - \theta_2)\right] + \frac{1}{2}mg\ell\left(3\cos\theta_1 + \cos\theta_2\right).
$$

$$
\dot{\theta}_1 = \frac{6}{m\ell^2}\frac{2p_{\theta_1} - 3\cos(\theta_1 - \theta_2)p_{\theta_2}}{16 - 9\cos^2(\theta_1 - \theta_2)}
$$

$$
\dot{\theta}_2 = \frac{6}{m\ell^2}\frac{8p_{\theta_2} - 3\cos(\theta_1 - \theta_2)p_{\theta_1}}{16 - 9\cos^2(\theta_1 - \theta_2)}.
$$

$$
p_{\theta_1} = \frac{\partial L}{\partial \dot{\theta}_1} = \frac{1}{6}m\ell^2\left[8\dot{\theta}_1 + 3\dot{\theta}_2\cos(\theta_1 - \theta_2)\right]
$$

$$
p_{\theta_2} = \frac{\partial L}{\partial \dot{\theta}_2} = \frac{1}{6}m\ell^2\left[2\dot{\theta}_2 + 3\dot{\theta}_1\cos(\theta_1 - \theta_2)\right].
$$

$$
\dot{p}_{\theta_1} = \frac{\partial L}{\partial \theta_1} = -\frac{1}{2}m\ell^2\left[\dot{\theta}_1\dot{\theta}_2\sin(\theta_1 - \theta_2) + 3\frac{g}{\ell}\sin\theta_1\right]
$$

$$
\dot{p}_{\theta_2} = \frac{\partial L}{\partial \theta_2} = -\frac{1}{2}m\ell^2\left[-\dot{\theta}_1\dot{\theta}_2\sin(\theta_1 - \theta_2) + \frac{g}{\ell}\sin\theta_2\right].
$$

Trebuchet

$$\begin{aligned} L &= \text{Kinetic Energy} - \text{Potential Energy} \\ &= \frac{1}{2}m\left(v_1^2 + v_2^2\right) + \frac{1}{2}I\left(\dot{\theta}_1^2 + \dot{\theta}_2^2\right) - mg\left(y_1 + y_2\right) \\ &= \frac{1}{2}m\left(\dot{x}_1^2 + \dot{y}_1^2 + \dot{x}_2^2 + \dot{y}_2^2\right) + \frac{1}{2}I\left(\dot{\theta}_1^2 + \dot{\theta}_2^2\right) - mg\left(y_1 + y_2\right) \end{aligned}$$

$$L = \frac{1}{6}m\ell^2\left[\dot{\theta}_2^2 + 4\dot{\theta}_1^2 + 3\dot{\theta}_1\dot{\theta}_2\cos(\theta_1 - \theta_2)\right] + \frac{1}{2}mg\ell\left(3\cos\theta_1 + \cos\theta_2\right).$$

$$\dot{\theta}_1 = \frac{6}{m\ell^2}\frac{2p_{\theta_1} - 3\cos(\theta_1 - \theta_2)p_{\theta_2}}{16 - 9\cos^2(\theta_1 - \theta_2)}$$

$$\dot{\theta}_2 = \frac{6}{m\ell^2}\frac{8p_{\theta_2} - 3\cos(\theta_1 - \theta_2)p_{\theta_1}}{16 - 9\cos^2(\theta_1 - \theta_2)}.$$

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$$\dot{p}_{\theta_2} = \frac{\partial L}{\partial \theta_2} = -\frac{1}{2}m\ell^2\left[-\dot{\theta}_1\dot{\theta}_2\sin(\theta_1 - \theta_2) + \frac{g}{\ell}\sin\theta_2\right].$$

Where to get the RT patch

- Stable Repository
  - **git://git.kernel.org/pub/scm/linux/kernel/git/rt/linux-stable-rt.git**
- Patches
  - http://www.kernel.org/pub/linux/kernel/projects/rt/
- Wiki
  - https://rt.wiki.kernel.org/index.php/Main_Page

What is a Real-time OS?

- Deterministic
  - Does what you expect to do
  - When you expect it will do it
- Does not mean fast
  - Would be nice to have throughput
  - Guarantying determinism adds overhead
  - Provides fast “worst case” times
- Can meet your deadlines
  - If you have done your homework

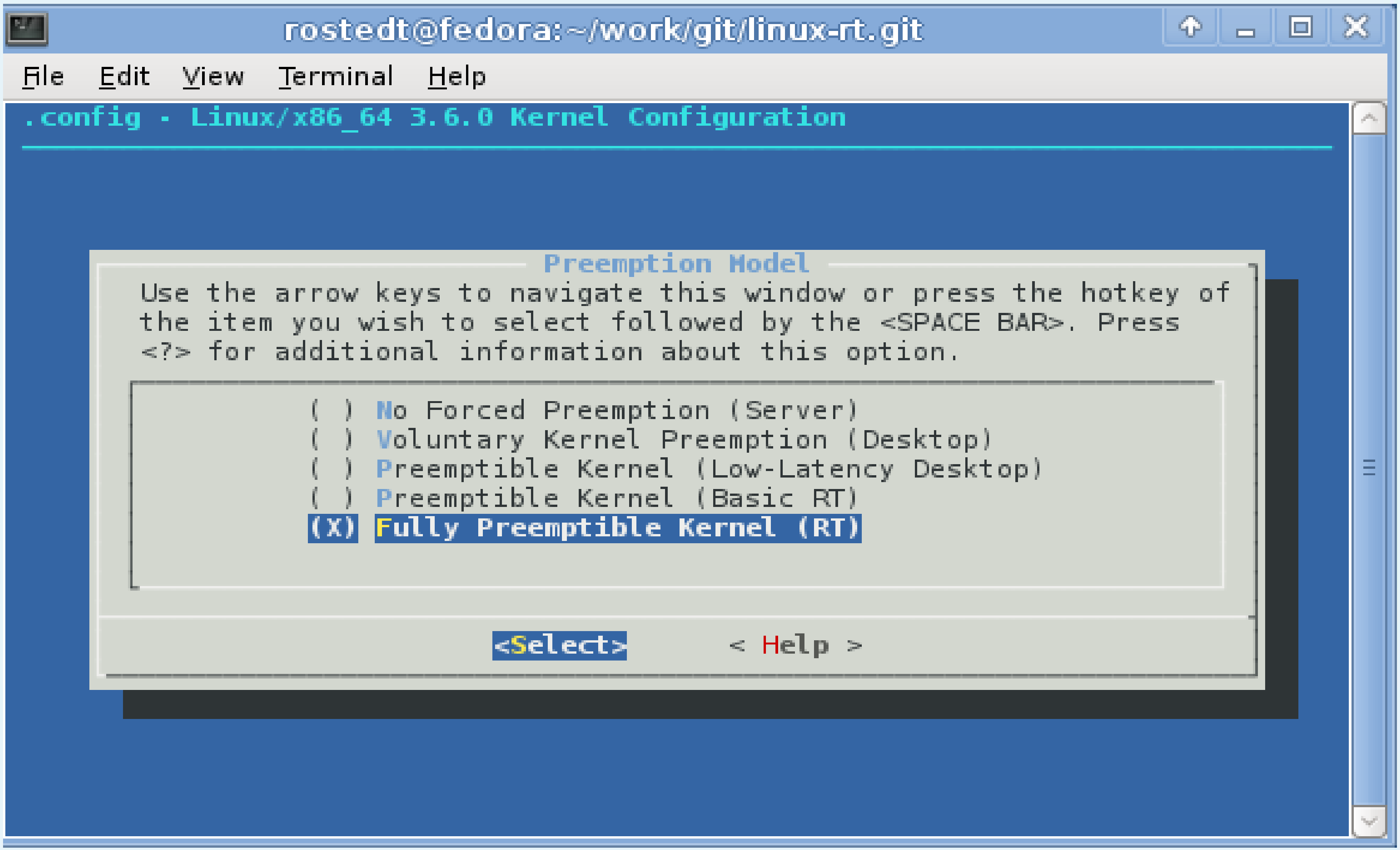
What is a Real-time OS?

- Dependent on the system
  - SMI
  - Cache
  - Bus contention
- hwlat detector
  - New enhancements coming

The Goal of PREEMPT_RT

- 100% Preemptible kernel
  - Not actually possible, but lets try regardless
  - Remove disabling of interrupts
  - Removal of disabling other forms of preemption
- Quick reaction times!
  - bring latencies down to a minimum

Menuconfig



rostedt@fedora:~/work/git/linux-rt.git
File Edit View Terminal Help
.config - Linux/x86_64 3.6.0 Kernel Configuration
Preemption Model
Use the arrow keys to navigate this window or press the hotkey of the item you wish to select followed by the <SPACE BAR>. Press <?> for additional information about this option.
( ) No Forced Preemption (Server)
( ) Voluntary Kernel Preemption (Desktop)
( ) Preemptible Kernel (Low-Latency Desktop)
( ) Preemptible Kernel (Basic RT)
(X) Fully Preemptible Kernel (RT)
<Select>
< Help >

No Preemption

- Server
  - Do as most possible with as little scheduling overhead
- Never schedule unless a function explicitly calls schedule()
- Long latency system calls.
- Back in the days of 2.4 and before.

Voluntary Preemption

- might_sleep();
    - calls might_resched(); calls _cond_resched()
  - Used as a debugging aid to catch functions that might schedule called from atomic operations.
  - need_resched – why not schedule?
  - schedule only at “preemption points”.

Preemptible Kernel

- Robert Love's CONFIG_PREEMPT
- SMP machines must protect the same critical sections as a preemptible kernel.
- Preempt anywhere except within spin_locks and some minor other areas (preempt_disable).
- Every spin_lock acts like a single “global lock” WRT preemption.

Preemptible Kernel (Basic RT)

- Mostly to help out debugging PREEMPT_RT_FULL
- Enables parts of the PREEMPT_RT options, without sleeping spin_locks
- Don't worry about it (It will probably go away)

Fully Preemptible Kernel
The RT Patch

- PREEMPT_RT_FULL
- Preempt everywhere! (except from preempt_disable and interrupts disabled).
- spin_locks are now mutexes.
- Interrupts as threads
  - interrupt handlers can schedule
- Priority inheritance inside the kernel (not just for user mutexes)

Sleeping spin_lock

- CONFIG_PREEMPT is a global lock (like the BKL but for the CPU)
- sleeping spin_locks contains critical sections that are localized to tasks
- Must have threaded interrupts
- Must not be in atomic paths (preempt_disable or local_irq_save)
- Uses priority inheritance
  - Not just for futexes

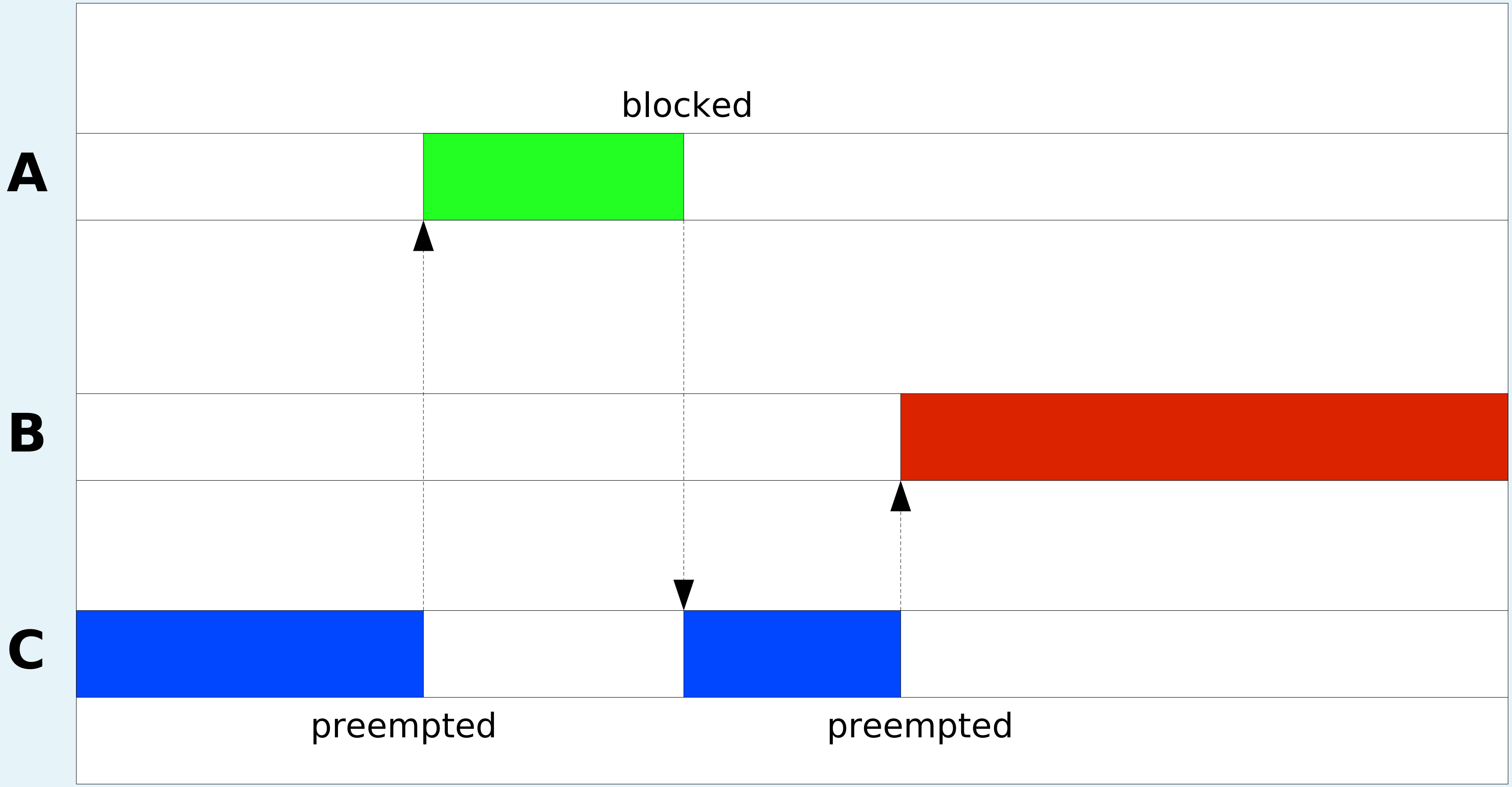
PREEMPT_LAZY

- RT can preempt almost anywhere
- Spinlocks that are now mutexes can be preempted
  - Much more likely to cause contention
- Do not preempt on migrate_disable()
  - used by sleepable spinlocks
- Increases throughput on non-RT tasks

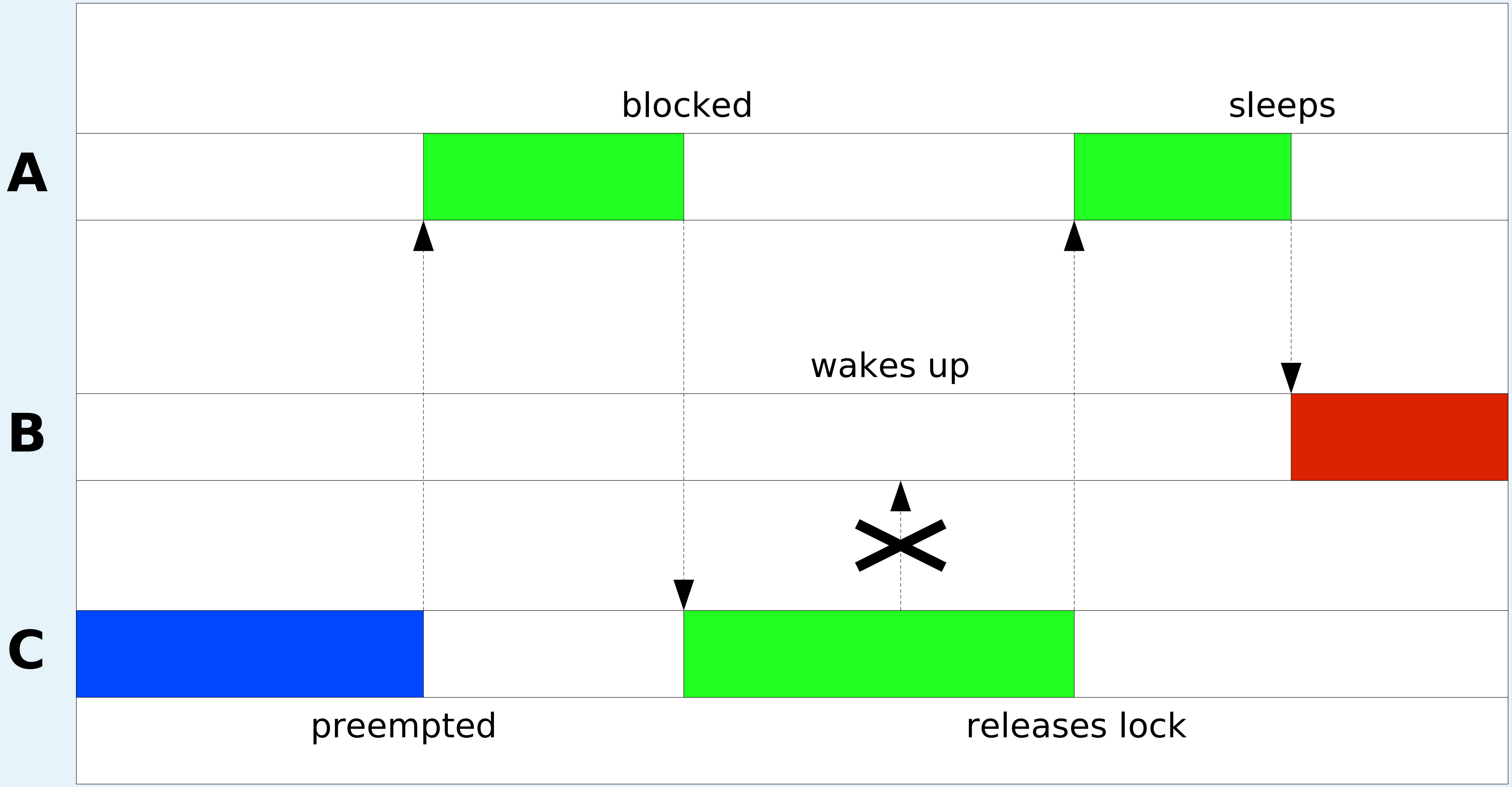
Priority Inheritance

- Prevents unbounded priority inversion
  - Can't stop bounded priority inversion
- Is a bit complex
  - One owner per lock
  - Why we hate rwlocks
    - will explain more later

Unbounded Priority Inversion



Priority Inheritance



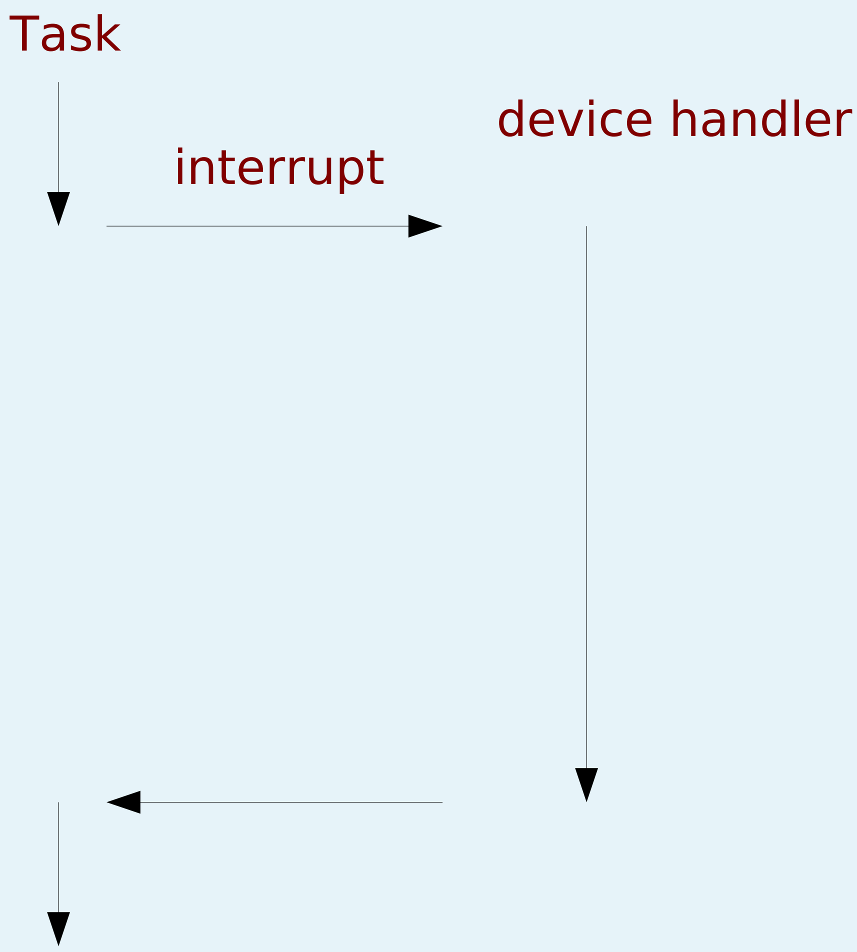
raw_spin_lock

- Some spin_locks should never be converted to a mutex
- Same as current mainline spin_locks
- Should only be used for scheduler, rtmutex implementation, debugging/tracing infrastructure and for timer interrupts.
- Timer drivers for clock events (HPET, PM timer, TSC)
- Exists today in current mainline, with no other purpose as to annotate what locks are special (Thank you Linus!)

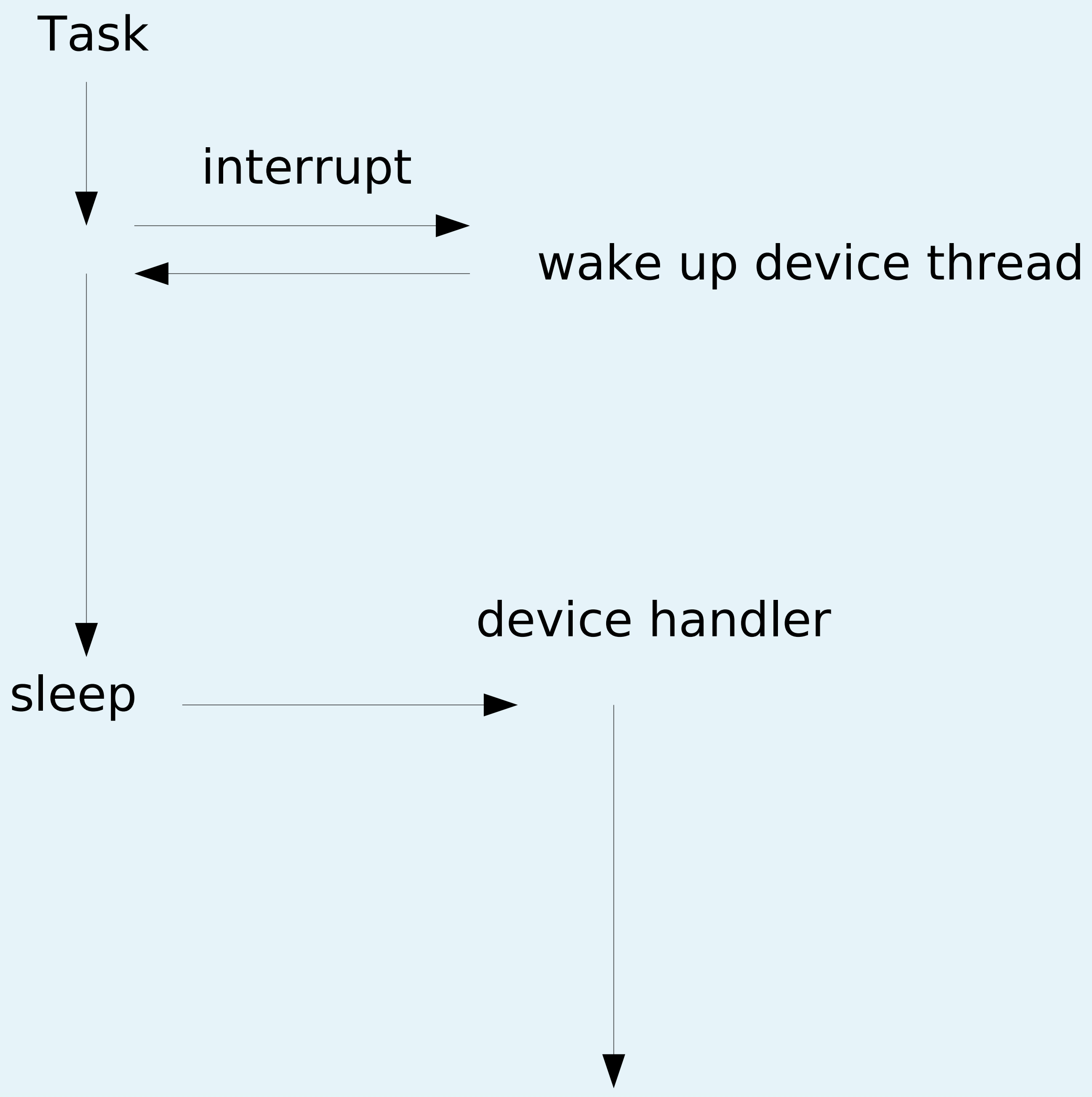
Threaded Interrupts

- Lowers Interrupt Latency
- Prioritize interrupts even when the hardware does not support it.
- Less noise from things like “updatedb”

Interrupt Latency



Interrupt Thread



Non-Thread IRQs

- Timer interrupt
  - Manages the system (sends signals to others about time management)
- IRQF_TIMER
  - Denotes that a interrupt handler is a timer
- IRQF_NO_THREAD
  - When the interrupt must not be a thread
  - Don't use unless you know what you are doing
  - Must not call spin_locks

Threaded Interrupts

- Now in mainline
  - Per device interrupts
  - One big switch (all irqs as threads)
- Per device is still preferred
  - except for non shared interrupts
  - Shared devices can have different priorities
- One big switch
  - Handlers the same, but just threaded

Threaded Interrupts

- request_threaded_irq()
  - Tells system driver wants handler as thread
- Driver registers two functions
  - handler
    - If NULL must have thread_fn
      - Disables irq lin
      - handler assigned by system
    - non-NULL is called by hard irq
  - thread_fn (optional)
    - When set makes irq threaded
    - non-NULL to disable device only

Threaded Interrupts

- The kernel command line parameter
  - threadirqs
- threadirqs forces all IRQS to have a “special” handler” and uses the handler as thread_fn
  - except IRQF_NOTHREAD, IRQF_PER_CPU and IRQF_ONESHOT

local_irq_disable

- EVIL!!!
- This includes local_irq_save
- No inclination to what it's protecting
- SMP unsafe
- High latency

spin_lock_irqsave

- The Angel
- PREEMP_RT does **NOT** disable interrupts
  - Remember, in PREEMPT_RT spin_locks are really mutexes
  - low latency
- Tight coupling between critical sections and disabling interrupts
- Gives a hint to what it's protecting
  - (spin_lock name)

preempt_disable

- local_irq_disable's younger sibling
- Also does not give a hint to what it protects
- preempt_enable_no_resched
  - only should be used within preempt_disabled locations
  - __preempt_enable_no_resched
    - Only use before directly calling schedule()

per_cpu

- Avoid using:
  - local_irq_save
  - preempt_disable
  - get_cpu_var (well, you can, but be nice – it calls preempt_disable)
- Do:
  - pinned CPU threads
  - get_cpu_light()
  - get_local_var(var)
  - local_lock[_irq[save]](var)

get_cpu_light()

- Non PREEMPT_RT is same as get_cpu()
- On PREEMPT_RT disables migration

get_local_var(var)

- Non PREEMPT_RT is same as get_cpu_var(var)
- On PREEMPT_RT disables migration

local_lock[_irq[save]](var)

- Non PREEMPT_RT is just preempt_disable()
- On PREEMPT_RT grabs a lock based on var
  - disables migration
- Use local_unlock[_irq[restore]](var)
- Labels what you are protecting

rwlocks

- Death of Determinism
- Writes must wait for unknown amount of readers
- Recursive locking
- Possible strange deadlock due to writers
  - Yes, affects mainline too!

NOHZ

- idle nohz best for power management
- Not nice for responses from idle
- Process nohz coming soon (nothing to do with idle nohz, but uses same ideas and in some cases, same code)

Real-Time User Space

- Don't use priority 99
- Don't implement spin locks
  - Use priority inheritance futexes
  - PTHREAD_PRIO_INHERIT
- Avoid slow I/O
- mmap passing data
- mlock_all()
  - at least the stuff you know you need

Questions?