Linux Interrupt Processing and Kernel Thread

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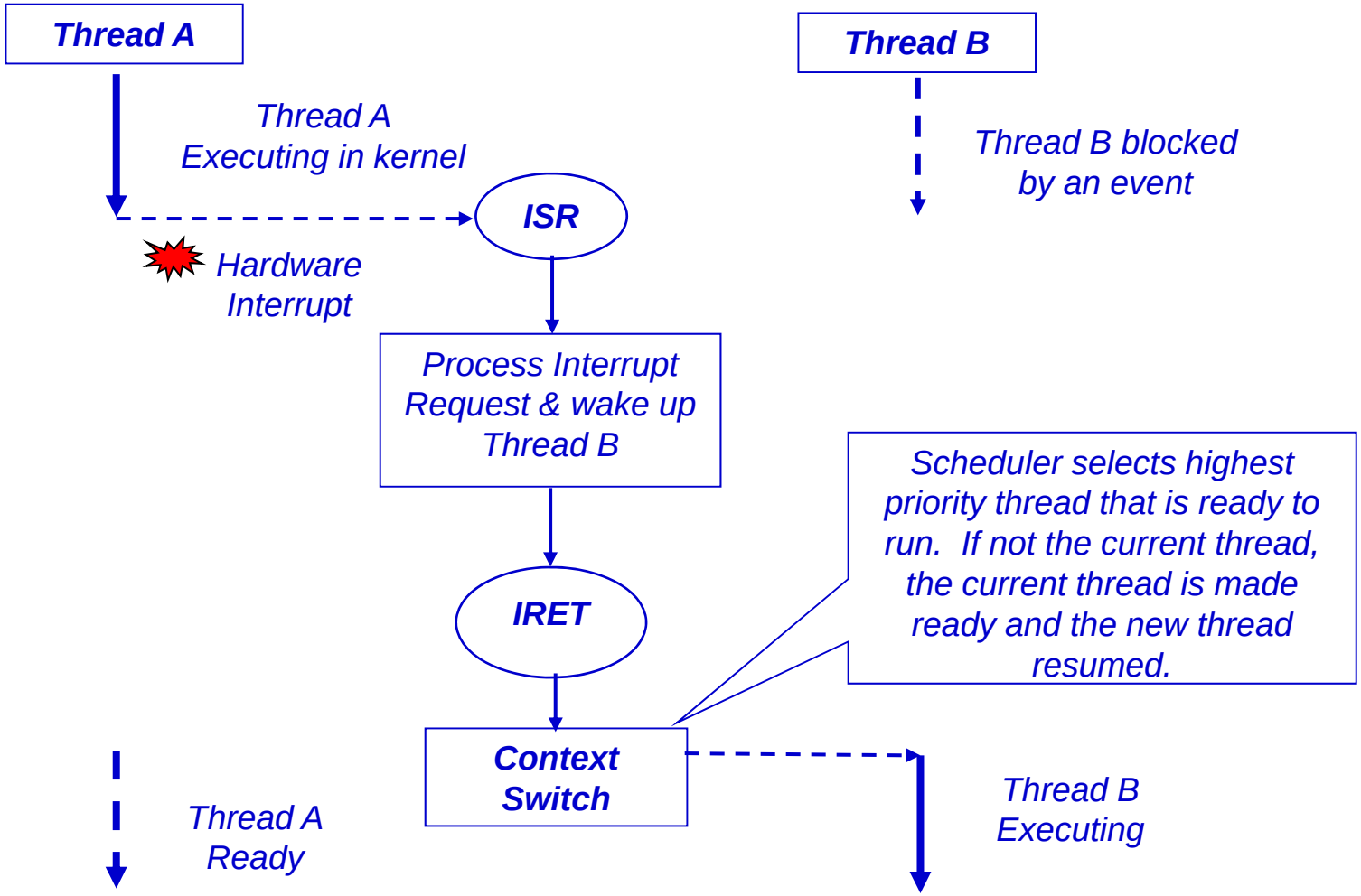
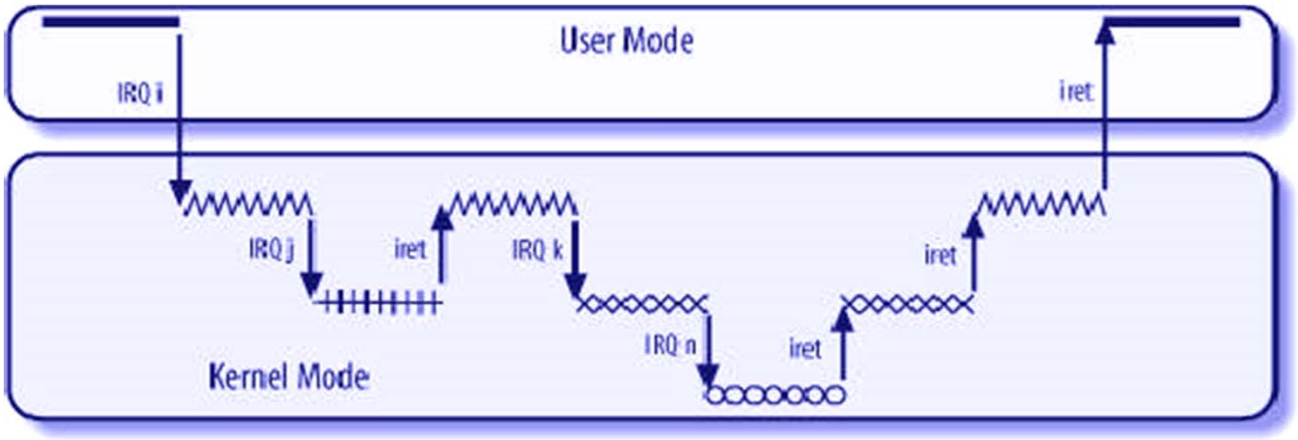
Preemptive Context Switching



(ftp://ftp.prenhall.com/pub/esm/electrical_engineering.s-037/lewis/powerpoint/chapter_7.zip)

Nested Execution of Handlers

- **Generally nesting of kernel code paths is allowed with certain restrictions**
- **Exceptions can nest only 2 levels**
  - Original exception and possible Page Fault
  - Exception code can block
- **Interrupts can nest arbitrarily deep, but the code can never block (nor should it ever take an exception)**

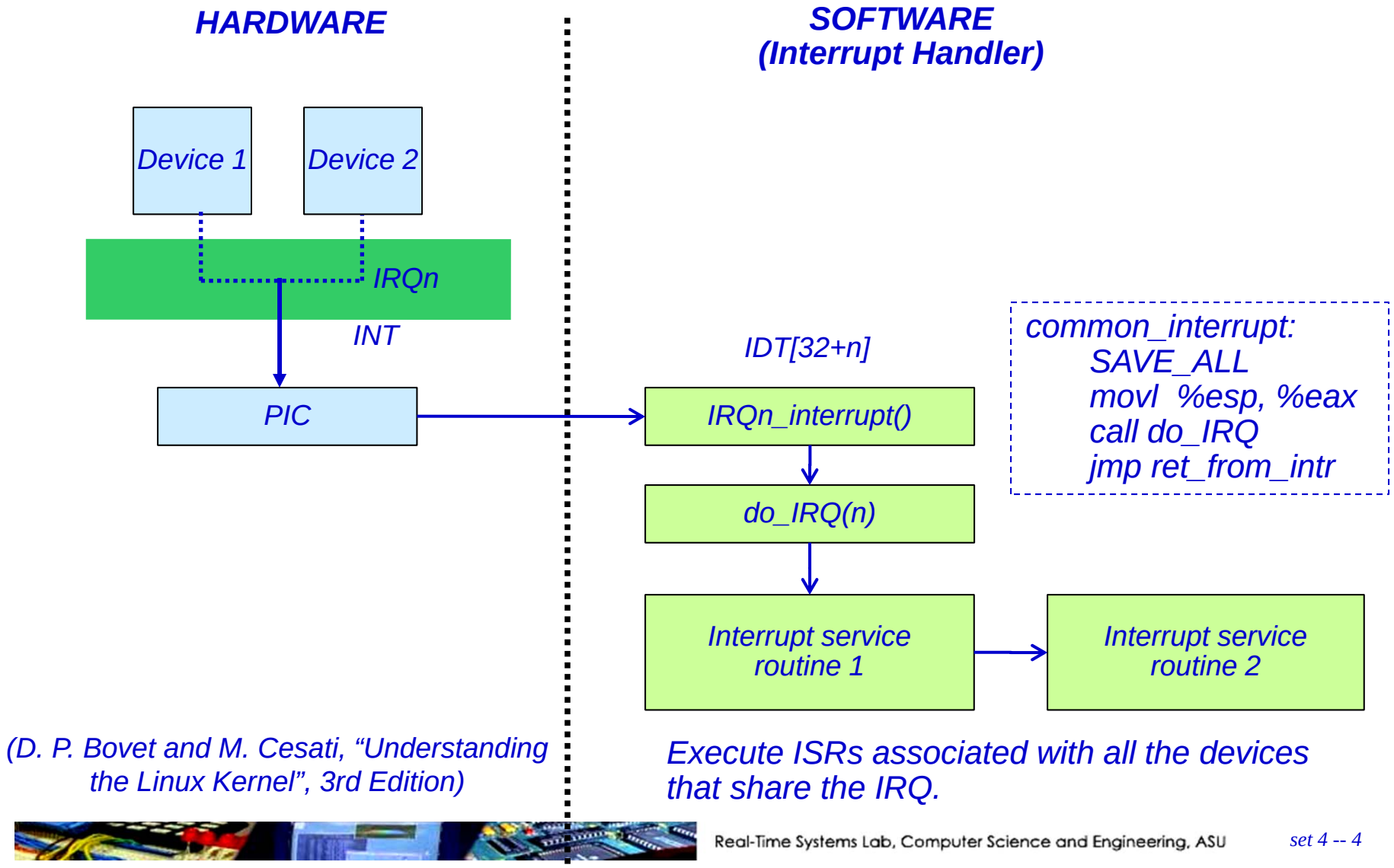


(D. P. Bovet and M. Cesati, "Understanding the Linux Kernel", 3rd Edition)

Interrupt Handling

- **Depends on the type of interrupts**
  - *I/O interrupts*
  - *Timer interrupts*
  - *Interprocessor interrupts*
- **Unlike exceptions, interrupts are "out of context" events**
- **Generally associated with a specific device that delivers a signal on a specific IRQ**
  - IRQs can be shared and several ISRs may be registered for a single IRQ
- **ISRs is unable to sleep, or block**
  - *Critical:* to be executed within the ISR immediately, with maskable interrupts disabled
  - *Noncritical:* should be finished quickly, so they are executed by theISR immediately, with the interrupts enabled
  - *Noncritical deferrable:* deferrable actions are performed by means of separate functions

I/O Interrupt Handling



(D. P. Bovet and M. Cesati, "Understanding the Linux Kernel", 3rd Edition)

Execute ISRs associated with all the devices that share the IRQ.

Why ISR Bottom Half?

- **To have low interrupt latency -- to split interrupt routines into**
  - a `top half', which receives the hardware interrupt and
  - a `bottom half', which does the lengthy processing.
- **Top halves have following properties (requirements)**
  - need to run as quickly as possible
  - run with some (or all) interrupt levels disabled
  - are often time-critical and they deal with HW
  - do not run in process context and cannot block
- **Bottom halves are to defer work later**
  - “Later” is often simply “not now”
  - Often, bottom halves run immediately after interrupt returns
  - They run with all interrupts enabled
- **Code in the Linux kernel runs in one of three contexts:**
  - Process context, kernel thread context, and Interrupt.

A World of Bottom Halves

- **Multiple mechanisms are available for bottom halves**
- **softirq: (available since 2.3)**
  - A set of 32 statically defined bottom halves that can run simultaneously on any processor
    - Even 2 of the same type can run concurrently
  - Used when performance is critical
  - Must be registered statically at compile-time
- **tasklet: (available since 2.3)**
  - Are built on top of softirqs
  - Two different tasklets can run simultaneously on different processors
    - But 2 of the same type cannot run simultaneously
  - Used most of the time for its ease and flexibility
  - Code can dynamically register tasklets
- **work queues: (available since 2.5)**
  - Queueing work to be performed in process context

Softirqs

- **Softirqs are reentrant functions that are serialized on a given CPU, but can run concurrently across CPUs,**
  - reduce the amount of locking needed
- **Statically allocated at compile-time**
- **In 2.6.7 kernel, only 6 prioritized softirqs are used**

  HI_SOFTIRQ, *TIMER_SOFTIRQ,*
  NET_TX_SOFTIRQ, *NET_RX_SOFTIRQ,*
  SCSI_SOFTIRQ, *TASKLET_SOFTIRQ*
- **A softirq often raised from within interrupt handlers and never preempts another softirq**
- **Pending softirqs are checked for and executed (call *do_softirq()*) in the following places:**
  - After processing a HW interrupt
  - By the ksoftirqd kernel thread
  - By code that explicitly checks and executes pending softirqs

Tasklets

- **Tasklets are typically functions used by device drivers for deferred processing of interrupts,**
  - can be statically or dynamically enqueued on either the TASKLET_SOFTIRQ or the HI_SOFTIRQ softirq
- **Tasklets can only run on one CPU at a time, and are not required to be reentrant (run only once)**
  - a tasklet does not begin executing before the handler has completed.
  - locking between the tasklet and other interrupt handlers may still be required
  - locking between multiple tasklets
- **A more formal mechanism of scheduling software interrupts**
  - Tasklet struct -- the macro *DECLARE_TASKLET(name, func, data)*
  - *tasklet_schedule(&tasklet_struct) schedules a* tasklet for execution.
  - invokes ***raise_softirq_irqoff( )*** to activate the softirq
  - run in software interrupt context with the result that all tasklet code must be atomic.

WorkQueues

- **To request that a function be called at some future time.**
  - tasklets execute quickly, for a short period of time, and in atomic mode
  - workqueue functions may have higher latency but need not be atomic
- **Run in the context of a special kernel process (worker thread)**
  - more flexibility and workqueue functions can sleep.
  - they are allowed to block (unlike deferred routines)
  - No access to user space
- ***A workqueue (****workqueue_struct****) must be explicitly created***
- **Each workqueue has one or more dedicated "kernel threads", which run functions submitted to the queue.**
  - work_struct structure to submit a task to a workqueue

    *DECLARE_WORK(name, void (*function)(void *), void *data);*
- **A shared, default workqueue provided by the kernel.**

Work Queue Activation

- **The queue_work() routine prepares a work_struct descriptor (holding a function) for a work queue and then:**
  - Checks whether the function to be inserted is already present in the work queue (work->pending field equal to 1); if so, terminates
  - Adds the work_struct descriptor to the work queue list, and sets work->pending to 1
  - If a worker thread is sleeping in the more_work wait queue of the local CPU's cpu_workqueue_struct descriptor, this routine wakes it up
- **The kernel offers a predefined work queue called *events*, which can be freely used by every kernel developer**
  - saves significant system resources when the function is seldom invoked
  - must be careful not to enqueue functions that could block for a long period

Example of Work Structure and Handler

```
#include <linux/kernel.h>
#include <linux/module.h>
#include <linux/workqueue.h>
MODULE_LICENSE("GPL");

static struct workqueue_struct *my_wq;          // work queue
typedef struct {                                // work
        struct work_struct  my_work;
        int x;
} my_work_t;

my_work_t  *work, *work2;

static void my_wq_function( struct work_struct *work)      // function to be call
{
        my_work_t *my_work = (my_work_t *)work;
        printk( "my_work.x %d\n", my_work->x );
        kfree( (void *)work );
        return;
}
```

(http://www.ibm.com/developerworks/linux/library/l-tasklets/index.html)

Example of Work and WorkQueue Creation

```
int init_module( void )
{
        int ret;
        my_wq = create_workqueue("my_queue");          // create work queue
        if (my_wq) {
                work = (my_work_t *)kmalloc(sizeof(my_work_t), GFP_KERNEL);
                if (work) {                                    // Queue work (item 1)
                INIT_WORK( (struct work_struct *)work, my_wq_function );
                work->x = 1;
                ret = queue_work( my_wq, (struct work_struct *)work );
                        }

                work2 = (my_work_t *)kmalloc(sizeof(my_work_t), GFP_KERNEL);
                if (work2) {                                   // Queue work (item 2)
                INIT_WORK( (struct work_struct *)work2, my_wq_function );
                work2->x = 2;
                ret = queue_work( my_wq, (struct work_struct *)work2 );
                }
        }
        return 0;
}
```

(http://www.ibm.com/developerworks/linux/library/l-tasklets/index.html)