Writing Device Drivers Under Linux

Linux Kernel Programming

Kernel programming

- Not that different from user mode programming
  - Especially if you're used to threads
- Preemption and reentrancy issues
- Memory allocation is different

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Modes of Operation

- User mode
- Kernel mode
- Interrupt level processing
- Bottom half processing

User mode

- Normal user programs execute in user mode
- Each user process has its own "task context"
- User mode execution continues until:
  - it makes a system call (which may block)
  - its time quanta is exhausted

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Kernel mode

- Entered when a user program makes a system call
- Executes within the calling process's context
- Kernel programs may block which will allow another process to run
- Kernel mode is non-preemptible
  - But some routines (like kmalloc()) can block

Interrupt level processing

- Entered when a device causes interrupt
- Must not block
- May interrupt kernel mode processing

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Bottom half processing

- Much like BSD "software interrupts"
- Like interrupt level processing
  - Must not block
  - May interrupt kernel mode processing
- May be interrupted by hardware interrupts

Requesting resources

- Allocating kernel memory
- Registering an IRQ handler
- Request a DMA channel

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Allocating kernel memory

- To allocate memory: kmalloc(size, priority)
  - Common priorities
    - GFP_KERNEL --- normal kernel allocation
    - GFP_ATOMIC --- for use in interrupt routines
    - GFP_DMA --- to get DMA buffers
- Free memory using kfree(ptr)

Registering an IRQ handler

- request_irq(irq, handler, irqflags, dev_name, dev_id)
- See include/linux/sched.h for function prototype
- dev_name contains a string for /proc/interrupts
- dev_id is an void * unique id which must be passed to kfree

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IRQ flags

- Uses name space stolen from sigaction sa_flags for historical reasons
- SA_INTERRUPT --- use "fast" interrupt processing
- SA_SHIRQ --- allow the irq to be shared with other devices
- SA_SAMPLE_RANDOM --- use this interrupt to sample randomness

Reserving a DMA channel

- request_dma(chan, device_name) to request a DMA channel
- device_name is a string for /proc/dma
- kfree_dma(chan) to free a DMA channel

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Accessing user memory -- 2.0

- error = verify_area(type, ptr, size)
  - Type is VERIFY_READ or VERIFY_WRITE
- memcpy_fromfs(to, from_user, len)
- memcpy_tofs(to_user, from, len)
- get_user(x, ptr)
- put_user(x, ptr)

Deprecated 2.0 user access methods

- get_fs_byte,word,long(addr)
- put_fs_byte,word,long(x, addr)
- Won't work in future versions of the kernel

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Accessing user_memory -- 2.1.8

- error = copy_from_user(to, from_user, len)
- error = copy_to_user(to_user, from, len)
- error = get_user(x, ptr)
- error = put_user(x, ptr)
- All of these now return 0 or -EFAULT

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Sleeping and waking

- In kernel mode, you may wish to put a process to sleep until some condition is true
- Define a wait queue
  - struct wait_queue *queue = NULL;
- To sleep waiting on a queue
  - sleep_on(&queue) / interruptible_sleep_on(&queue)
- To wake up processes waiting on a queue
  - wake_up(&queue) / wake_up_interruptible(&queue)

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Avoiding race conditions

- Try to avoid them altogether
- If absolutely necessary use semaphores
- Declare a semaphore
  - struct semaphore sem = MUTEX;
- To use the semaphore
  - down(&sem)
  - up(&sem)

Kernel modules

- Implement your device driver as a loadable kernel module if at all possible
- Much faster compile/debug/test cycle
- Module specific initialization and cleanup
  - init_module()
  - cleanup_module()
- /proc/ksyms interface for kernel function linkage

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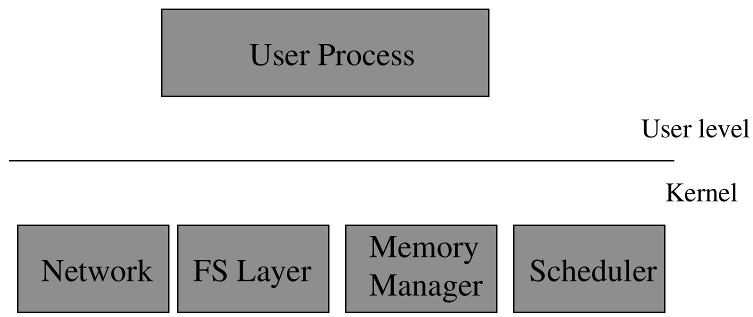
Kernel Organization



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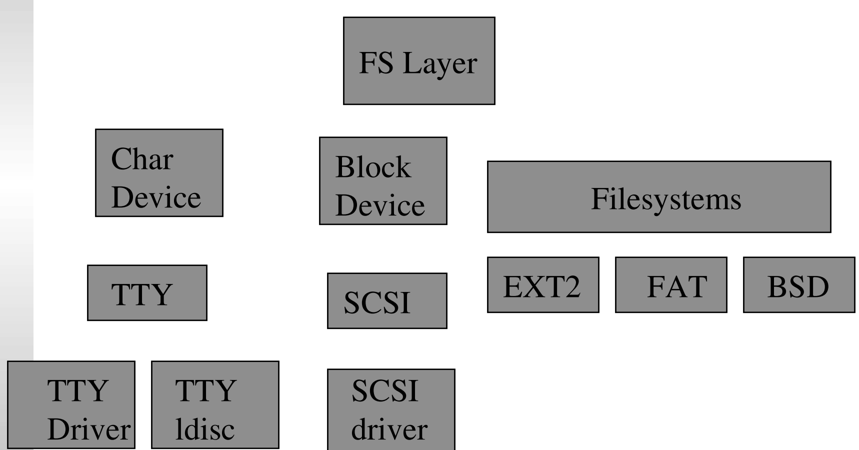
Kernel Organization II



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Device Abstractions

- character device
  - PS/2 mouse driver
  - high-level tty layer
    - tty line discpline
    - tty device driver
- block device
  - scsi layer
    - low-level scsi driver

Device Abstractions II

- High-level network code
  - Network protocol layer
    - IP
    - Appletalk
  - Network device drivers
    - 3c509 driver
    - PPP tty line discpline(!)

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Device numbers

- Used to address devices
  - Major device number
  - Minor device number
  - Separate number spaces for character and block devices
- Major device numbers assigned centrally
- A character, tty, or block device driver needs a one or more major numbers

Filesystem Abstractions

- Please turn to page 1 in the example source code book
- Basic abstractions used by all objects in the filesystem
  - Inodes (and inode operations)
  - Files (and file operations)

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Inodes

- Representation of a filesystem object
  - Files
  - Sockets
  - Devices
- Filesystem layer creates an inode data structure in response to an iget()
  - Contains inode info from the filesystem
  - Inode operations dispatch table

The Inode_operations Table

- Table containing function pointers
- Operations performed on (unopened) inode
  - Main operation of interest is open()
  - Other operations such as unlink(), rename(), operate on directories
- The pointer to the inode_ops table is dynamic!
  - Changes to support inheritance

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Files

- Represents an opened filesystem object
- A file descriptor points to a file structure
- Like the inode structure, contains a pointer to a function table, the file_operations table

The File_operations Table

- Operations performed on file descriptors
  - read
  - write
  - lseek
- The pointer to the file operations table is also dynamic
  - Changes to support inheritance
  - When a hangup occurs on a tty

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