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Linux Driver Ecosystem Bash privm X Server gcc firefoX ● Process Management ssh Memory Management File Systems Device Control Networking Architecture Dependent Code Character Devices Memory Manager Filesystem Types Block Devices Network Subsystem IP Filesystem Concurrency MultiTasking Virtual Memory Files & Dirs: The VFS Tys & Device Access Connectivity CPU Memory Disks & CDs Consoles, etc Network Interfaces 8. Kernel Source Organization Kernel Source include net drivers block fs mm kernel arch char mtd/ide net pci ...usbserial asm-linux arm powerpc sparc x86 ... 9. The Locations & Config Files ● Kernel Source Path: /usr/src/linux ● Std Modules Path: - /lib/modules/kernel/... ● Module Configuration: /etc/modprobe.conf ● Kernel Windows: - /proc - /sys ● System Logs: /var/log/messages 10. The Commands ● lsmod ● insmod ● modprobe ● rmmod ● dmesg ● objdump ● nm ● cat /proc/11. The Kernel's C ● ctor & dtor - init_module, cleanup_module ● printf - printk ● Libraries - /kernel ● Headers - /include 12. The Init Code static int __init mfd_init(void) { printk(KERN INFO "mfd registered"); ... return 0; } module_init(mfd_init); ... module_exit(mfd_exit); ... } module_exit(mfd_exit); 14. Usage of printk ● ● Constant String for Log Level - KERN EMERG "" /* system is unusable */ - KERN ALERT "" /* action must be taken immediately */ - KERN CRIT "" /* critical conditions */ - KERN ERR "" /* error conditions */ - KERN WARNING "" /* warning conditions */ - KERN NOTICE "" /* normal but significant condition */ - KERN INFO "" /* informational */ - KERN DEBUG "" /* debug-level messages */ ● ● printf like arguments 15. The Other Basics & Ornaments ● Headers - #include - #include - #include ● MODULE_LICENSE("GPL"); ● MODULE_AUTHOR("Emertxe"); ● MODULE_DESCRIPTION("First Device Driver"); 16. Building the Module ● Our driver needs - The Kernel Headers for Prototypes - The Kernel Functions for Functionality - The Kernel Build System & the Makefile for Building ● Two options - Building under Kernel Source Tree ● Put our driver under drivers folder ● Edit Kconfig(s) & Makefile to include our driver - Create our own Makefile to do the right invocation 17. Our Makefile ifeq (\$KERNELRELEASE,.) obj-m += .o else KERNEL_SOURCE = PWD := \$(shell pwd) default: \$(MAKE) -C \$(KERNEL_SOURCE) SUBDIRS=\$(PWD) clean endif 18. Try Out your First Driver 19. Character Drivers 20. Major & Minor Number ● ls -l /dev ● Major is to Driver; Minor is to Device ● (>= 2,6,0) - dev t: 12 & 20 bits for major & minor ● - MAJOR(dev t dev) - MINOR(dev t dev) - MKDEV(int major, int minor) 21. Registering & Unregistering the Device Driver - int register_chrdev_region(dev t first, unsigned int count, char *name); - int alloc_chrdev_region(dev t *dev, unsigned int firstminor, unsigned int cnt, char *name); ● Unregistering the Device Driver - void unregister_chrdev_region(dev t first, unsigned int count); ● Header: 22. The file operations ● #include ● struct file_operations - int (*open)(struct inode *, struct file *); - int (*release)(struct inode *, struct file *); - ssize_t (*read)(struct file *, char __user *, size_t, loff_t *); - ssize_t (*write)(struct file *, const char __user *, size_t, loff_t *); - struct module owner = THIS_MODULE; /linux/module.h> /* - loff_t (*lseek)(struct file *, loff_t, int); - int (*ioctl)(struct inode *, struct file *, unsigned int, unsigned long); 23. User level I/O ● int open(const char *path, int oflag, ...) ● int close(int fd); ● ssize_t write(int fd, const void *buf, size_t nbytes); ● ssize_t read(int fd, void *buf, size_t nbytes); ● int ioctl(int d, int request, ...) - The ioctl() function manipulates the underlying device parameters of special files. - The argument d must be an open file descriptor. - The second argument is a device-dependent request code. 24. The file & inode structures ● struct file - mode t f_mode - loff_t f_pos - unsigned int f_flags - struct file_operations *f_op - void *private_data ● struct inode - unsigned int imajor(struct inode *); - unsigned int iminor(struct inode *); 25. Registering the file operations ● #include ● 1st way initialization: - struct cdev *my_cdev = cdev_alloc(); - my_cdev->owner = THIS_MODULE; - my_cdev->ops = &my_fops; ● 2nd way initialization: - struct cdev my_cdev; - cdev_init(&my_cdev, &my_fops); - my_cdev.owner = THIS_MODULE; - my_cdev.ops = &my_fops; 26. Registering the file operations... ● The Registration - int cdev_add(struct cdev *cdev, dev_t num, unsigned int count); ● The Unregistration - void cdev_del(struct cdev *cdev); 27. Registering/Unregistering Old Way ● Registering the Device Driver - int register_chrdev(unsigned int major, const char *name, struct file_operations *fops); ● Unregistering the Device Driver - int unregister_chrdev(unsigned int major, const char *name); 28. The read flow struct file ----- f_count f_flags f_mode ----- f_pos ----- ... , ssize_t my_read(struct file *f, char __user *buf, size_t cnt, loff_t *off) Buffer (in the driver) Buffer (in the application or libc) Kernel Space (Non-swappable) User Space (Swappable) copy to user 29. /dev/null read & write ssize_t my_read(struct file *f, char __user *buf, size_t cnt, loff_t *off) { ... return read cnt; } ssize_t my_write(struct file *f, char __user *buf, size_t cnt, loff_t *off) { ... return wrote cnt; } 30. The mem device read ssize_t my_read(struct file *f, char __user *buf, size_t cnt, loff_t *off) { ... if (copy to user(buf, cnt) == 0) { return read cnt; } ... return read cnt; } 31. The mem device write ssize_t my_write(struct file *f, char __user *buf, size_t cnt, loff_t *off) { ... if (copy from user(to, buf, cnt) == 0) { return -EFAULT; } ... return wrote cnt; } 32. Dynamic Device Node & Classes ● Class Operations - struct class *class_create(struct module *owner, char *name); - void class_destroy(struct class *cl); ● Device into & Out of Class - struct class device *device_create(struct class *cl, NULL, dev_t devnum, NULL, const char *fmt, ...) - void device_destroy(struct class *cl, dev_t devnum); 33. The I/O Control API ● int (*ioctl)(struct inode *, struct file *, unsigned int cmd, unsigned long arg) ● int (*unlocked_ioctl)(struct file *, unsigned int cmd, unsigned long arg) ● Command -> ... -> - Macros ● _IO, _IOR, _IOW, _IOWR - Parameters ● type (Magic character) [15:8] ● number (index) [7:0] ● size (param type) [29:16] 34. The I/O Control API ● Macro Usage _IO(type, index) | _IOR | _IOWR[type, index, datatype/size] 35. Module Parameters ● - Macros ● module_param(name, type, perm) ● module_param_array(name, type, num, perm) ● Perm (is a bitmask) - 0 - S_IRUGO - S_IWUSR | S_IRUGO - Loading ● insmod driver.ko name=10 36. x86 Architecture A B 37. Memory Access 38. Physical Vs Virtual Memory ● The kernel Organizes Physical memory in to pages - Page size Depends on Arch ● X86-based 4096 bytes ● On 32-bit X86 system Kernel total Virtual address space - Total 4GB (pointer size) - Kernel Configuration Splits 4GB in to ● 3GB Virtual Sp for US ● 1GB Virtual Sp for Kernel - 128MB KDS - Virtual Address also called "Logical Address" 39. Memory Access from Kernel Space ● Virtual Address on Physical Address - #include ● unsigned long __get_free_pages(flags, order); etc ● void free_pages(addr, order); etc - #include ● void *kmalloct(size_t size, gfp_t flags); - GFP_ATOMIC, GFP_KERNEL, GFP_DMA ● void kfree(void *obj); - #include ● void *vmalloc(unsigned long size); ● void vfree(void *addr); 40. Memory Access from Kernel Space... ● Virtual Address for Bus/I/O Address - #include ● void *ioremap(unsigned long offset, unsigned long size); ● void iounmap(void *addr); ● I/O Memory Access - #include ● unsigned int ioread8[8][16][32](void *addr); ● unsigned int iowrite8[8][16][32](u8[8][16][32] value, void *addr); ● Barriers - #include : void barrier(void); - #include : void r[wb]mb(void); 41. Hardware Access 42. I/O Accesses from Kernel Space ● I/O Port Access - #include ● unsigned int in[bw]l[un]signed port); ● void out[bw]l[un]signed [char]short[int] value, unsigned port); 43. Hands-On the Hardware

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