CSCI315 – Operating Systems Design

Department of Computer Science
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Linux File System and I/O

Ch 20.7-20.8

This set of notes is based on notes from the textbook authors, as well as L. Felipe Perrone, Joshua Stough, and other instructors.
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FILE SYSTEM

File Systems

- To the user, Linux's file system appears as a hierarchical directory tree obeying UNIX semantics
- Internally, the kernel hides implementation details and manages the multiple different file systems via an abstraction layer, that is, the virtual file system (VFS)
- The Linux VFS is designed around object-oriented principles and is composed of four components:
  - A set of definitions that define what a file object is allowed to look like
    - The **inode object** structure represent an individual file
    - The **file object** represents an open file
    - The **superblock object** represents an entire file system
    - A **dentry object** represents an individual directory entry

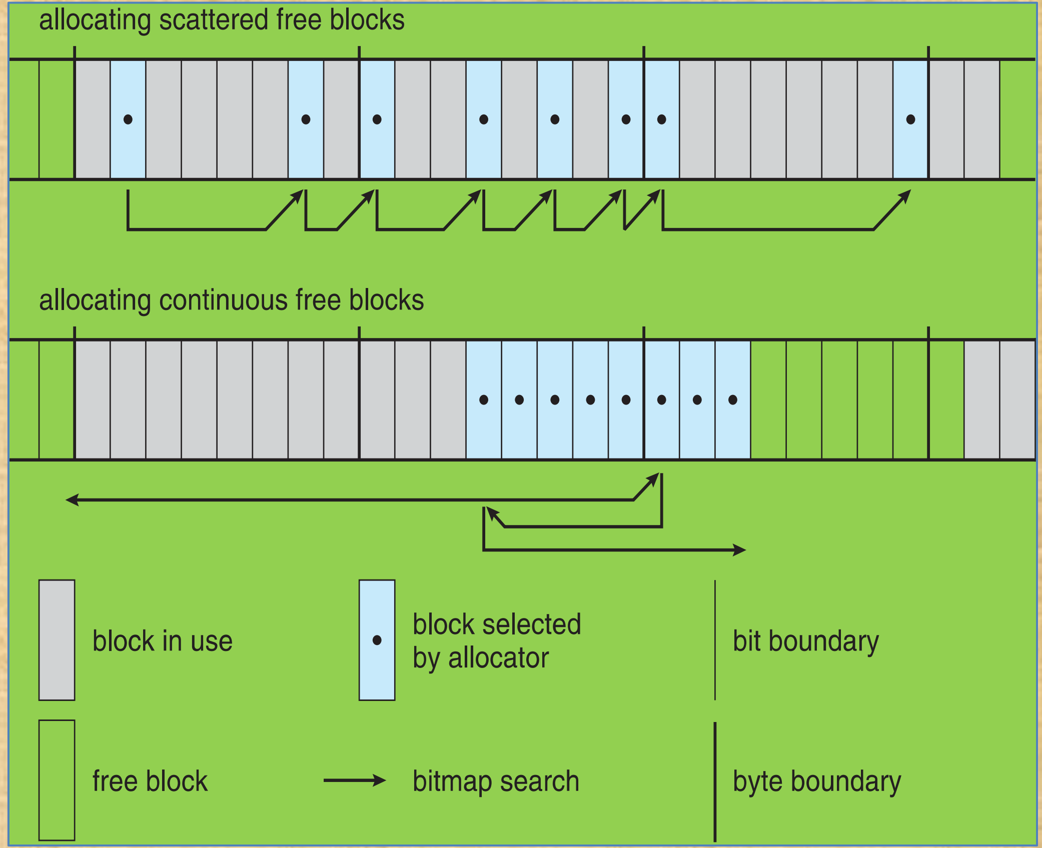
The Linux ext3 File System

- **ext3** is standard on disk file system for Linux
  - Uses a mechanism similar to that of BSD Fast File System (FFS) for locating data blocks belonging to a specific file
  - Supersedes older **extfs**, **ext2** file systems
  - Work underway on **ext4** adding features like extents
  - Of course, many other file system choices with Linux systems

The Linux ext3 File System (Cont.)

- The main differences between ext2fs and FFS concern their disk allocation policies
  - In FFS, the disk is allocated to files in blocks of 8Kb, with blocks being subdivided into fragments of 1Kb to store small files or partially filled blocks at the end of a file
  - ext3 does not use fragments; it performs its allocations in smaller units
    - The default block size on ext3 varies as a function of total size of file system with support for 1, 2, 4 and 8 KB blocks
  - ext3 uses cluster allocation policies designed to place logically adjacent blocks of a file into physically adjacent blocks on disk, so that it can submit an I/O request for several disk blocks as a single operation on a **block group**
  - Maintains bit map of free blocks in a block group, searches for free byte to allocate at least 8 blocks at a time

Ext2fs Block-Allocation Policies



The block numbers of allocated blocks are recorded in their respective **inodes**.

Journaling

- ext3 implements **journaling**, with file system updates first written to a log file in the form of **transactions**
  - Once in log file, considered committed
  - Over time, log file transactions replayed over file system to put changes in place
- On system crash, some transactions might be in journal but not yet placed into file system
  - Must be completed once system recovers
  - No other consistency checking is needed after a crash (much faster than older methods)
- Improves write performance on hard disks by turning random I/O into sequential I/O

The Linux Proc File System

- The **proc file system** does not store data, rather, its contents are computed on demand according to user file I/O requests
- **proc** must implement a directory structure, and the file contents within; it must then define a unique and persistent inode number for each directory and files it contains
  - It uses this inode number to identify just what operation is required when a user tries to read from a particular file inode or perform a lookup in a particular directory inode
  - When data is read from one of these files, **proc** collects the appropriate information, formats it into text form and places it into the requesting process's read buffer

The Linux Proc File System

The proc filesystem is a pseudo-filesystem which provides an interface to kernel data structures. It is commonly mounted at /proc. Typically, it is mounted automatically by the system.
-- Linux manual page (**man proc**)

Every process has such a file system that is created when the process is created. The file system is destroyed after the process exits.

The Linux Proc File System: Example

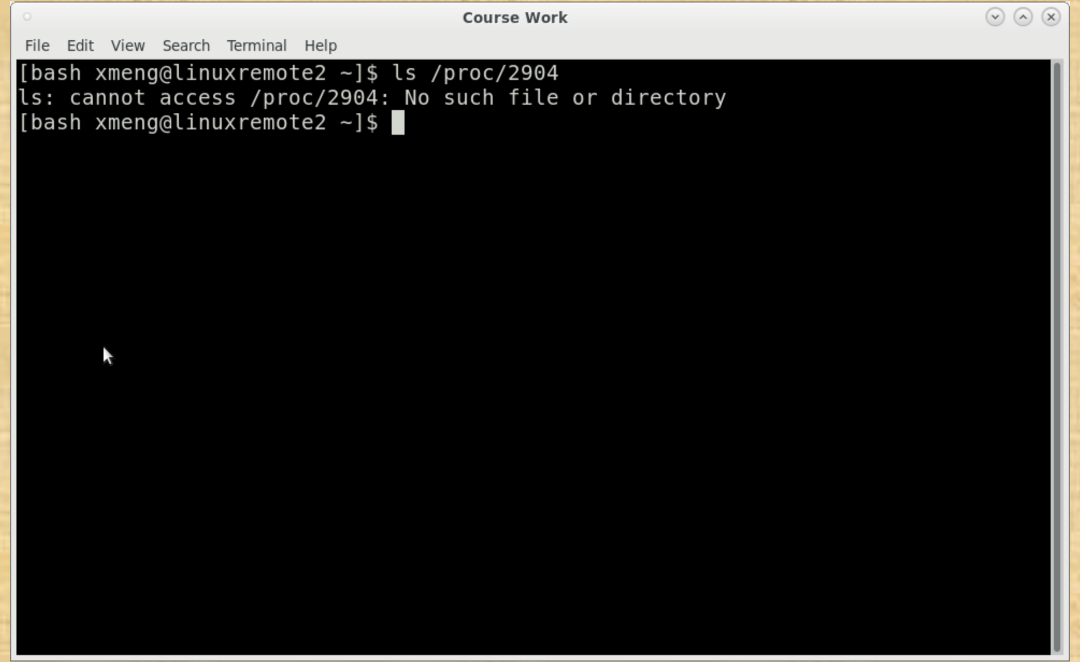
Course Work

File Edit View Search Terminal Help

```
[bash xmeng@linuxremote2 lectures]$ ls /proc/2904/
attr             cwd      map_files   oom_adj        schedstat  task
autogroup        environ  maps        oom_score      sessionid  timers
auxv             exe      mem         oom_score_adj  setgroups  uid_map
cgroup           fd       mountinfo   pagemap        smaps      wchan
clear_refs       fdinfo   mounts      patch_state    stack
cmdline          gid_map  mountstats  personality    stat
comm             io       net         projid_map     statm
coredump_filter  limits   ns          root           status
cpuset           loginuid numa_maps   sched          syscall
[bash xmeng@linuxremote2 lectures]$ ls -l /proc/2904/ | head
total 0
dr-xr-xr-x 2 xmeng cs 0 Nov 17 15:57 attr
-rw-r--r-- 1 xmeng cs 0 Nov 17 15:57 autogroup
-r-------- 1 xmeng cs 0 Nov 17 15:57 auxv
-r--r--r-- 1 xmeng cs 0 Nov 17 15:57 cgroup
--w------- 1 xmeng cs 0 Nov 17 15:57 clear_refs
-r--r--r-- 1 xmeng cs 0 Nov 17 15:45 cmdline
-rw-r--r-- 1 xmeng cs 0 Nov 17 15:57 comm
-rw-r--r-- 1 xmeng cs 0 Nov 17 15:57 coredump_filter
-r--r--r-- 1 xmeng cs 0 Nov 17 15:57 cpuset
[bash xmeng@linuxremote2 lectures]$
```

After process 2904 was created

The Linux Proc File System: Example



After process 2904 completed.

LINUX INPUT AND OUTPUT

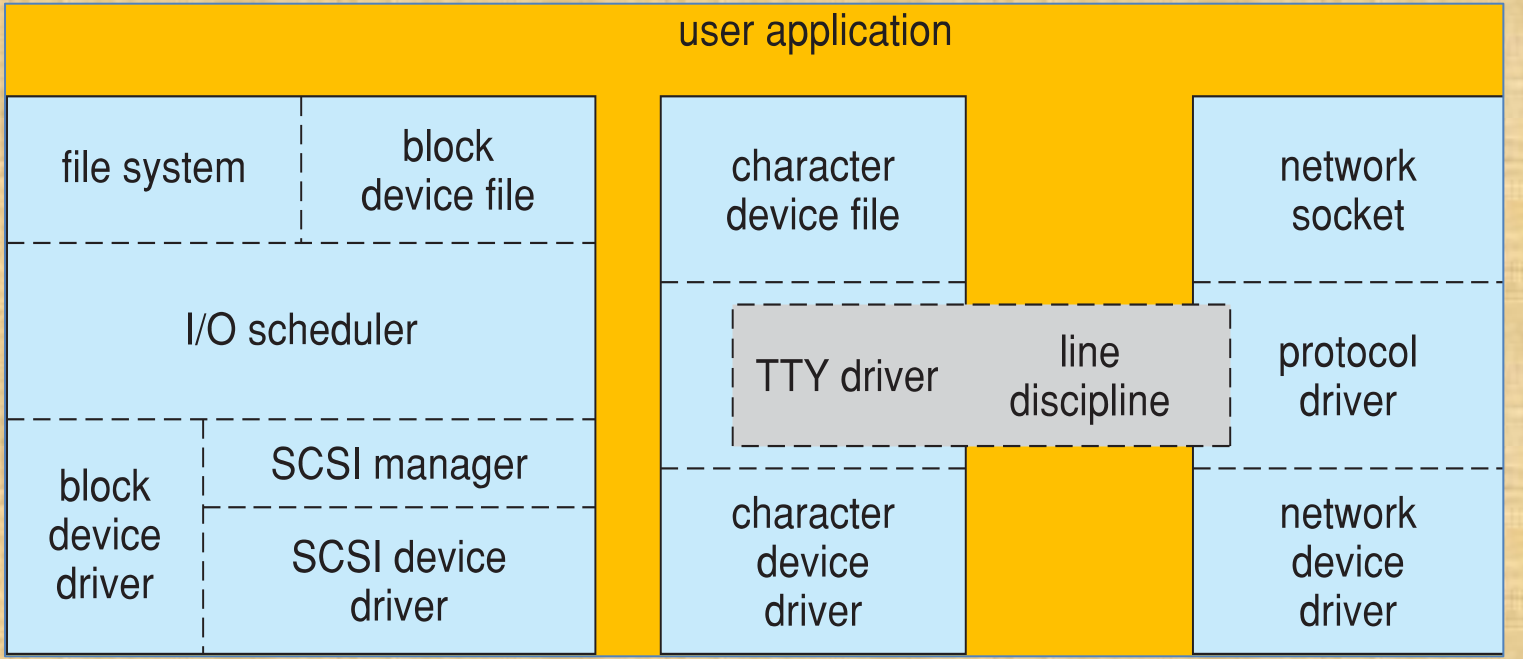
Input and Output

- The Linux device-oriented file system accesses disk storage through two caches:
  - Data is cached in the page cache, which is unified with the virtual memory system
  - Metadata is cached in the buffer cache, a separate cache indexed by the physical disk block
- Linux splits all devices into three classes:
  - **Block devices** allow random access to completely independent, fixed size blocks of data
  - **Character devices** include most other devices; they don't need to support the functionality of regular files
  - **Network devices** are interfaced via the kernel's networking subsystem

Block Devices

- Provide the main interface to all disk devices in a system
- The block buffer cache serves two main purposes:
  - it acts as a pool of buffers for active I/O
  - it serves as a cache for completed I/O
- The **request manager** manages the reading and writing of buffer contents to and from a block device driver
- Kernel 2.6 introduced **Completely Fair Queueing** (**CFQ**)
  - Now the default scheduler
  - Fundamentally different from elevator algorithms
  - Maintains set of lists, one for each process by default
  - Uses C-SCAN algorithm, with round robin between all outstanding I/O from all processes
  - Four blocks from each process put on at once

Device-Driver Block Structure



SCSI: Small Computer Systems Interface, a standard for I/O devices on PCs

Character Devices

- A device driver which does not offer random access to fixed blocks of data
- A character device driver must register a set of functions which implement the driver’s various file I/O operations
- The kernel performs almost no preprocessing of a file read or write request to a character device, but simply passes on the request to the device
- The main exception to this rule is the special subset of character device drivers which implement terminal devices, for which the kernel maintains a standard interface

Character Devices (Cont.)

- **Line discipline** is an interpreter for the information from the terminal device
  - The most common line discipline is **tty** discipline, which glues the terminal's data stream onto standard input and output streams of user's running processes, allowing processes to communicate directly with the user's terminal
  - Several processes may be running simultaneously, **tty** line discipline responsible for attaching and detaching terminal's input and output from various processes connected to it as processes are suspended or awakened by user
  - Other line disciplines also are implemented have nothing to do with I/O to user process – i.e., **PPP** and **SLIP** networking protocols