Virtual File System in Linux (Chap. 12 in Understanding the Linux Kernel)

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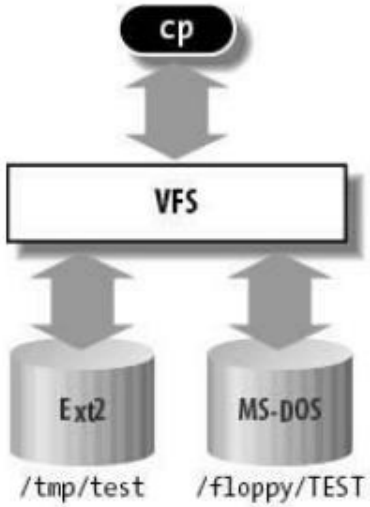
Outline

- Role of VFS
- VFS Data Structures
- Filesystem Types
- Filesystem Handling
- Pathname Lookup
- Implementation of VFS System Calls
- File Locking

Role of VFS

- A common interface to several kinds of filesystems
  - Ex: cp /floppy/TEST /tmp/test



(a)

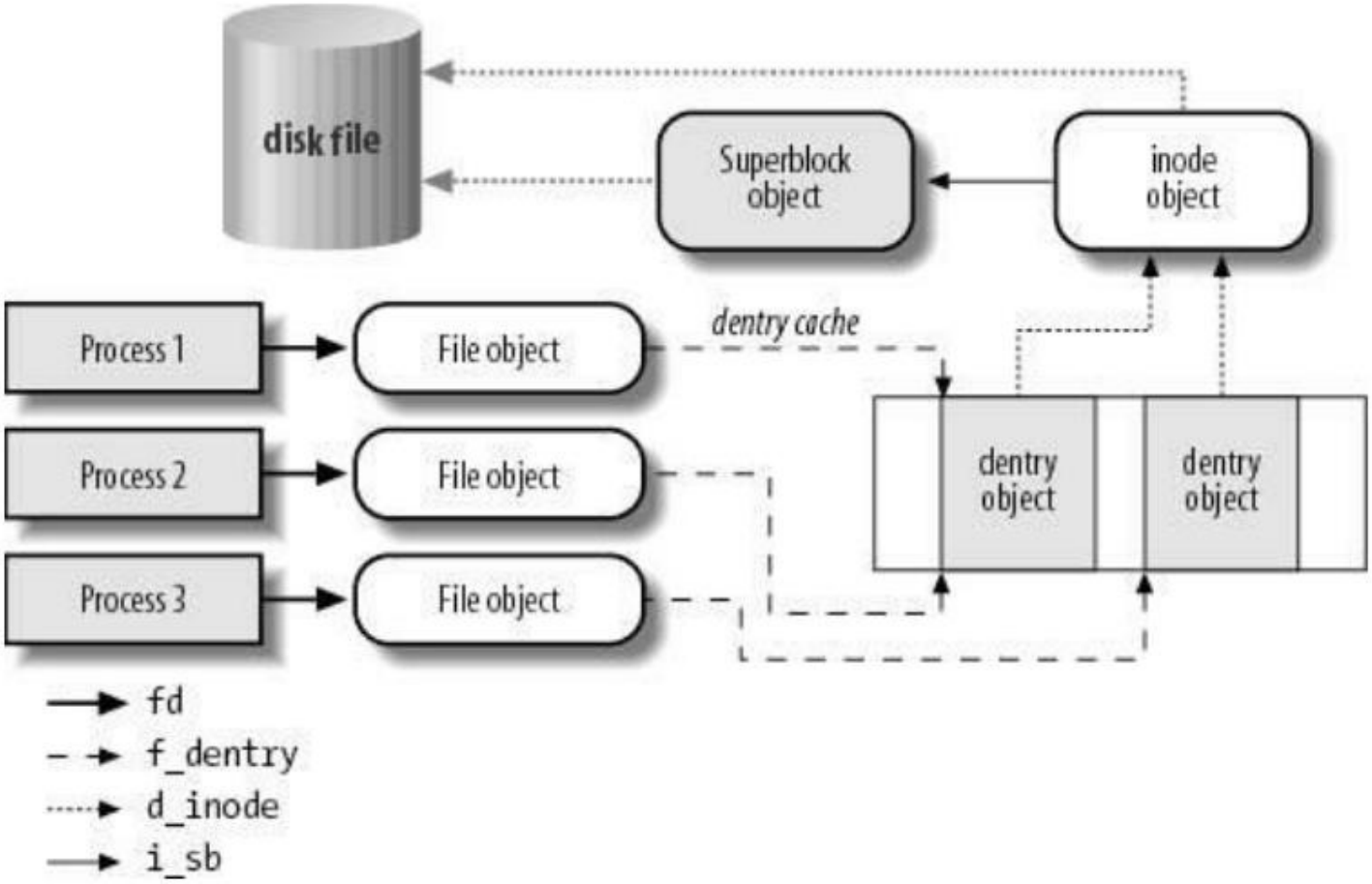
```
inf = open("/floppy/TEST", O_RDONLY, 0);
outf = open("/tmp/test",
       O_WRONLY|O_CREAT|O_TRUNC, 0600);
do {
    i = read(inf, buf, 4096);
    write(outf, buf, i);
} while (i);
close(outf);
close(inf);
```

(b)

- Filesystems supported by the VFS
  - Disk-based filesystems
    - Ext2, ext3, ReiserFS
    - Sysv, UFS, MINIX, VxFS
    - VFAT, NTFS
    - ISO9660 CD-ROM, UDF DVD
    - HPFS, HFS, AFFS, ADFS,
  - Network filesystems
    - NFS, Coda, AFS, CIFS, NCP
  - Special filesystems
    - E.g. /proc

The Common File Model

- Capable of representing all supported filesystems
  - Each specific filesystem implementation must translate its physical organization into VFS's common file model
  - E.g.: read(…): file->f_op->read(…);
- Object-oriented: data structures and associated operations
  - Superblock object: a mounted filesystem
  - Inode object: information about a file
  - File object: interaction between an open file and a process
  - Dentry object: directory entry


disk file
Superblock object
inode object
Process 1
File object
dentry cache
Process 2
File object
dentry object
dentry object
Process 3
File object
fd
f_dentry
d_inode
i_sb

Some System Calls Handled by the VFS

- Filesystem
  - Mount(), umount(), umount2()
  - Sysfs()
  - Statfs(), fstatfs(), statfs64(), fstatfs64(), ustat()
- Directories
  - Chroot(), pivot_root()
  - Chdir(), fchdir(), getcwd()
  - Mkdir(), rmdir()
  - Getdents(), getdents64(), readdir(), link(), unlink(), rename(), lookup_dcookie()
- Links
  - Readlink(), symlink()

- Files
  - Chown(), fchown(), lchown(), chown16(), fchown16(), lchown16()
  - Chmod(), fchmod(), utime()
  - Stat(), fstat(), lstat(), acess(), oldstat(), oldfstat(), oldlstat(), stat64(), lstat64(), fstat64()
  - Open(), close(), creat(), umask()
  - Dup(), dup2(), fcntl(), fcntl64()
  - Select(), poll()
  - Truncate(), ftruncate(), truncate64(), ftruncate64()
  - Lseek(). _llseek()
  - Read(), write(), readv(), writev(), sendfile(), sendfile64(), readahead()

- Others
  - Io_setup(), io_submit(), io_getevents(), io_cancel(), io_destroy()
  - Pread64(), pwrite64()
  - Mmap(), mmap2(), munmap(), madvise(), mincore(), remap_file_pages()
  - Fdatasync(), fsync(), sync(), msync()
  - Flock()
  - Setxattr(), lsetxattr(), fsetxattr(), getxattr(), lgetxattr(0, fgetxattr(), listxattr(), llistxattr(), flistxattr(), removexattr(), lremovexattr(), fremovexattr()

VFS Data Structures

- Superblock objects: super_block structure
  - (Table 12-2)
  - S_op: superblock operations – super_operations structure
    - Alloc_inode(), destroy_inode()
    - Read_inode(), dirty_inode(), write_inode(),
    - Put_inode(), drop_inode(), delete_inode()
    - Put_super(), write_super()
    - Sync_fs(), write_super_lockfs(), unlokcfs(), statfs(), remount_fs()
    - Clear_inode(), umount_begin()
    - Show_options(), quota_read(), quota_write()

- Inode objects (Table 12-3): inode structure
  - i_op: inode operations – inode_operations structure
    - Create(), lookup(), link(), unlink(), symlink()
    - Mkdir(), rmdir(), mknod(), rename()
    - readlink(), follow_link(), put_link()
    - Truncate(), permission(),
    - Setattr(), getattr(), setxattr(), getxattr(), listxattr(), removexattr()

- File objects: file structure (Table 12-4)
  - File operations
    - Llseek(), read(), aio_read(), write(), auio_write()
    - Readdir(), poll(), ioctl(), unlocked_ioctl(), compat_ioctl()
    - Mmap(), open(), flush(), release()
    - Fsync(), aio_fsync(), fasync(), lock()
    - Readv(), writev(), sendfile(), sendpage()
    - Get_unmapped_area(), check_flags(), dir_notify(), flock()

- Dentry objects: (Table 12-5)
  - States: free, unused, in use, negative
  - Dentry operations
    - D_revalidate()
    - D_hash()
    - D_compare()
    - D_delete()
    - D_release()
    - D_input()
- Dentry cache
  - A set of dentry objects
  - A hash table

Files Associated with a Process

- fs field: fs_struct structure (Table 12-6)
- files field: files_struct structure (Table 12-7)
  - fd: file descriptors
    - fd[0]: stdin
    - fd[1]: stdout
    - fd[2]: stderr
  - NR_OPEN: max # of file descriptors for a process
    - Usually 1,048,576

Special Filesystems

- (Tabel 12-8)
  - /dev/pts: pseudo terminal support
  - /proc: general access point to kernel data structures
  - /sys: general access point to system data
  - /proc/bus/usb: USB devices
  - …

Filesystem Type Registration

- File_system_type object: (Table 12-9)
- Fs_flags: (Table 12-10)

Filesystem Handling

- Root filesystem
- Mount point
- Namespaces: in Linux 2.6, each process might have its own tree of mounted filesystems
  - Namespace structure (Table 12-11)
- Filesystem mounting
  - It's possible in Linux to mount the same filesystem several times
  - Mounted filesystem descriptor: of type vfsmount (Tabel 12-12)
  - Mounting/unmounting the filesystem

- Pathname lookup
  - Pathname -> inode
  - Pathlookup(): return the nameidata structure (Table 12-15)
  - Standard pathname lookup
  - Parent pathname lookup
  - Lookup of symbolic links

Implementation of VFS System Calls

- Open()
- Read()
- Write()
- Close()

File Locking

- Advisory locks: by POSIX
  - Based on fcntl() system call
  - Possible to lock an arbitrary region of a file
- Mandatory locks: by System V Release 3
  - The kernel checks every invocation of open(), read(), write() system calls does not violate a mandatory lock
- Linux supports both + fcntl() and flock() system calls

Thanks for Your Attention!