File System Interface -- “A Tale of Two OS Components”

ECE595
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System Calls to UNIX File Systems

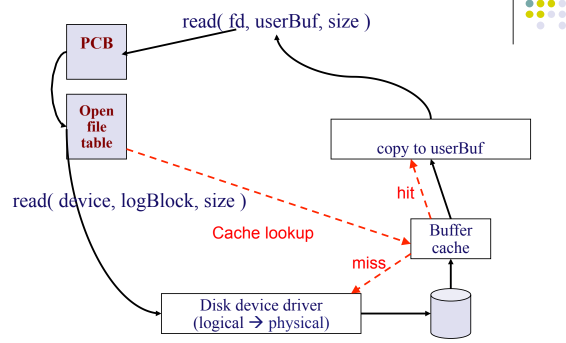
- 19 system calls into 6 categories:

Return file desp.	Assign inodes	Set file attr.	Process input/ output	Change file system	Modify view of file system
open close creat pipe dup	creat link unlink	chown chmod stat fstat	read write lseek	mount umount	chdir chroot

Roadmap

- Functionality (API)
  - Basic functionality
    - Disk layout
    - File operations (open, read, write, close)
  - Directories
- Performance
  - Disk allocation
  - Buffer cache
  - File System interface
  - Disk scheduling
- Reliability
  - FS level
  - Disk level: RAID

[lec20] Reading A Block



Modern disk drives are addressed as large one-dimensional arrays of logical blocks

File System Interface

- How do application programs typically access file data?
  - Explicit read/write operations (conventional)

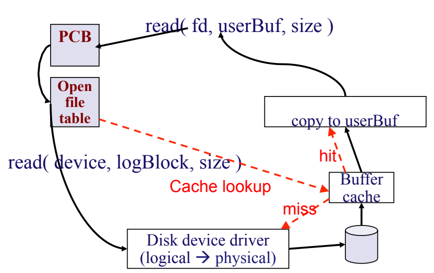
Read / Write Interface

- File data is explicitly copied between disk file and process memory
- Programs cannot directly access file data

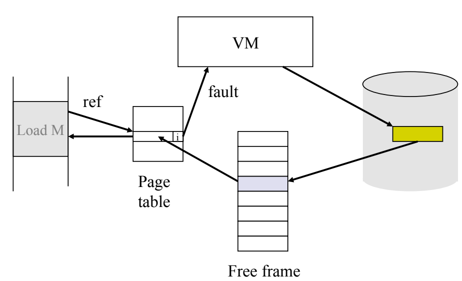
```
FileDescriptor fhandle;
int offset, length;
char buffer[1024];

fhandle = open("pathname");
read(fhandle, offset, buffer, length);
{read file data in buffer to do important computation};
Write(fhandle, offset, buffer, length)
close(fhandle);
```


Read / Write Interface – Problem 1

- Potential for double copies in mem

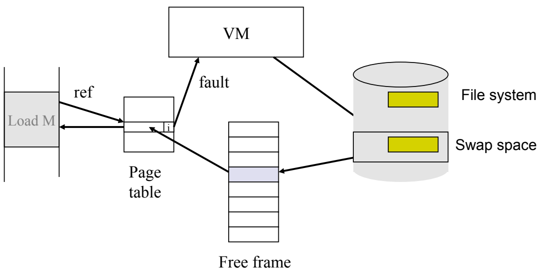


Essence of Demand Paging



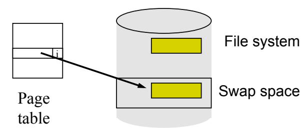
Disk is the backing store

[lec14] Demand Paging, Page Fault Handling

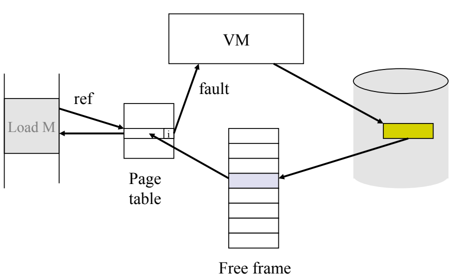


Read / Write Interface – Problem 2

- Potential for double paging on disk
  - process pages containing file data are paged out to paging space, leading to redundant copies of file data on disk

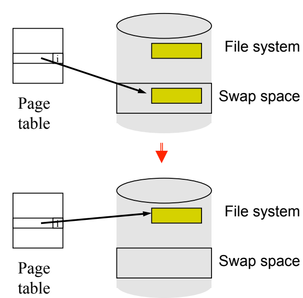


Essence of Demand Paging



Disk is the backing store

What if



Memory-mapped Files

- File is "mapped" into application's address space
  - by initializing virtual memory so that the file (directly) serves as backing store for a region of the application's address space

Memory-mapped Files (cont')

- Elegant integration of file system and virtual memory

```
FileDescriptor fhandle;
int offset, length;
char *address;

fhandle = open("pathname");
mmap(fhandle, offset, address, length);
{read/write file data by accessing memory range
              [address, address + length]};
munmap(address, length);
close(fhandle);
```

This is like after address = malloc()

Memory-mapped Files

- File is "mapped" into application's address space
  - by initializing virtual memory so that the file (directly) serves as backing store for a region of the application's address space
- File data is *demand paged* upon access to the mapped file
  - No double paging on disk
- Memory-mapped files do not go through buffer cache
  - No double copy in mem
    - Program accesses file data directly

Effects and Semantics of Memory-mapped Files

- Processes that map the same file share physical memory that caches file data
- Writes may not be immediately writen to the file on disk
  - Update periodically
  - Closing the file results in writing all to disk and removing the VM mapping

File caching implementation – Approach 1

- Set of kernel buffers maintained by the file system (buffer cache)
  - With a read/write API, can implement precise LRU
  - Not used for memory-mapped files
  - Need to decide how to partition physical memory among buffer cache and VM cache uses
    - Static partitioning during kernel configuration (BSD)
    - Dynamic adjustment of partitioning during runtime, e.g. keep miss frequencies of VM and buffer cache, and try to balance them (Linux)

File caching implementation – Approach 2

- File system memory-map all open files
  - Caching comes for free (just like normal VM)
  - No separate file cache
  - Flexible sharing of physical memory
  - VM page replacement policy does not discriminate between cached file data, and other VM pages
  - Open/read/write API can be supported by
    - open() → mapping opened files into kernel address space (also using VM)
    - read() / write() → copying from/to user buffers

Fun with memory-mapped files

- Inter-process communication
  - Virtual addresses of diff processes mapped to the same file
- File copying as Memory copying
  - Map files to virtual addresses
  - Do memory copying

Reading

- Chapters 11-12