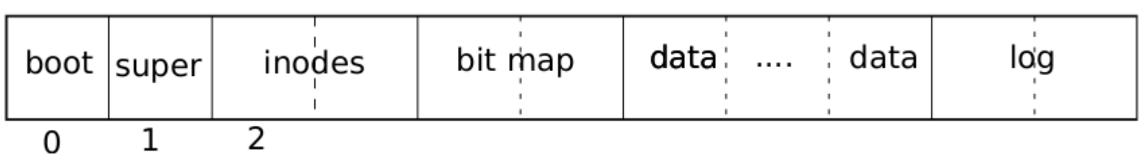
OPERATING SYSTEMS – ASSIGNMENT 4

FILE SYSTEMS

The xv6 file system provides Unix-like files, directories, and pathnames, and stores its data on an IDE disk for persistence. The file-system addresses several challenges:

- The file system needs on-disk data structures to represent the tree of named directories and files, to record the identities of the blocks that hold each file's content, and to record which areas of the disk are free.
- Accessing a disk is orders of magnitude slower than accessing memory, so the file system must maintain an in-memory cache of popular blocks.
- Different processes may operate on the file system at the same time, and must coordinate to maintain invariants.
- The file system must support crash recovery. That is, if a crash (e.g., power failure) occurs, the file system must still work correctly after a restart. The risk is that a crash might interrupt a sequence of updates and leave inconsistent on-disk data structures (e.g., a block that is both used in a file and marked free).

To do so, xv6 divides the disk into several sections, as shown in the Figure below. The file system does not use block 0 (it holds the boot sector). Block 1 is called the superblock, it contains metadata about the file system (the file system size in blocks, the number of data blocks, the number of inodes, and the number of blocks in the log). Blocks starting at 2 hold inodes. After those come bitmap blocks tracking which data blocks are in use. Most of the remaining blocks are data blocks. The blocks at the end of the disk hold the logging layer's log.

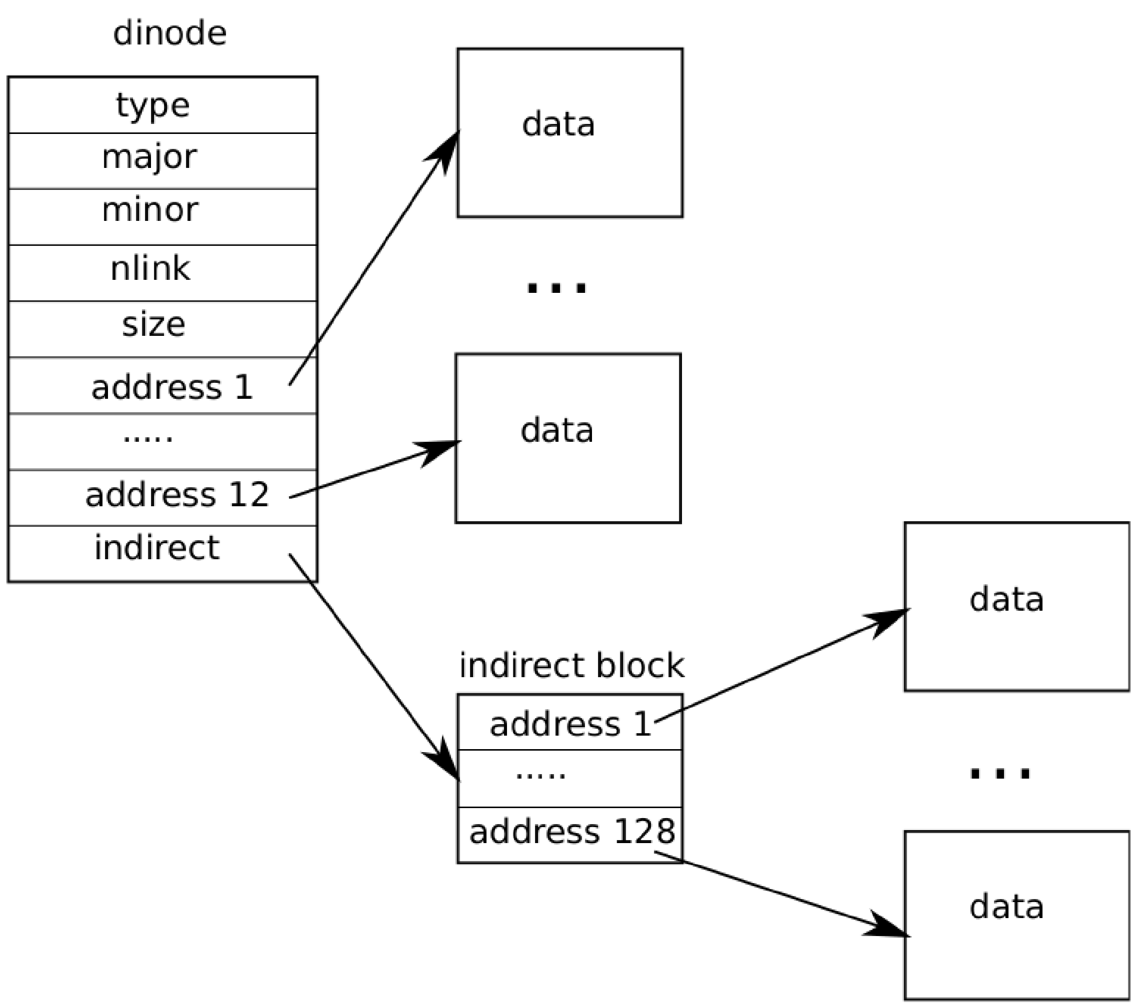


The term inode can have one of two related meanings. It might refer to the on-disk data structure (`struct dinode, fs.h`) containing a file's size and list of data block numbers. Or "inode" might refer to an in-memory inode (`struct inode, file.h`), which contains a copy of the on-disk inode as well as extra information needed within the kernel.

The on-disk inode is defined by a struct dinode. The type field distinguishes between files, directories, and special files (devices). A type of zero indicates that an on-disk inode is free. The nlink field counts the number of directory entries that refer to this inode, in order to recognize when the on-disk inode and its data blocks should be freed. The size field records the number of bytes of content in the file. The addrs array records the block numbers of the disk blocks holding the file's content.

```
// On−disk inode structure
struct dinode {
        short type; // File type
        short major; // Major device number (T_DEV only)
        short minor; // Minor device number (T_DEV only)
        short nlink; // Number of links to inode in file system
        uint size; // Size of file (bytes)
        uint addrs[NDIRECT+1]; // Data block addresses
};
```

The on-disk inode structure, struct dinode, contains a size and an array of block numbers (see Figure below). The inode data is found in the blocks listed in the dinode's addrs array. The first NDIRECT blocks of data are listed in the first NDIRECT entries in the array, these blocks are called direct blocks. The next NINDIRECT blocks of data are listed not in the inode but in a data block called the indirect block. The last entry in the addrs array gives the address of the indirect block.



The kernel keeps the set of active inodes in memory. struct inode is the in-memory copy of a struct dinode on disk. The kernel stores an inode in memory only if there are C pointers referring to that inode. The ref field counts the number of C pointers referring to the in-memory inode, and the kernel discards the inode from memory if the reference count drops to zero.

```
// in−memory copy of an inode
struct inode {
        uint dev; // Device number
        uint inum; // Inode number
        int ref; // Reference count
        int flags; // I_BUSY, I_VALID
        short type; // copy of disk inode
        short major;
        short minor;
        short nlink;
        uint size;
        uint addrs[NDIRECT+1];
};
```

A directory is implemented internally much like a file. Its inode has type T_DIR and its data is a sequence of directory entries. Each entry is a struct dirent (fs.h), which contains a name and an inode number. The name is at most DIRSIZ characters, if shorter, it is terminated by a NULL byte. Directory entries with inode number zero are free. The function dirlookup (fs.c) searches a directory for an entry with the given name. If it finds one, it returns a pointer to the corresponding inode.

```
struct dirent {
        ushort inum;
        char name[DIRSIZ];
};
```

In this assignment you will extend xv6's file system to support a simplified pseudo file-system, to be more specific - procfs (http://en.wikipedia.org/wiki/Procfs). Nice aspect of the Unix interface is that most resources in Unix are represented as special files, including devices such as the console, pipes, and of course, real files. Procfs is a pseudo file-system that the kernel creates in memory (i.e., it does not actually exist on the disk) and usually mounts it to the directory /proc. Procfs lets the kernel report information about processes and other system information to processes in a hierarchical structure (using file management system calls).

- Before implementing this assignment you must read chapter 6 from xv6 documentation (http://pdos.csail.mit.edu/6.828/2014/xv6/book-rev8.pdf).

A possible way to implement procfs is as a (virtual) device (like console). Originally, each device in xv6 supports only read/write operations. Since we want to implement a pseudo file-system (hierarchical structure), we extended the current implementation (in the assignment's repository) with all needed interfaces (**struct devsw**, file.h).

We mounted the procfs to "/proc" directory by creating an on-disk inode. The type of this inode is "device" (`T_DEV, stat.h`) and major (device number) = PROCFS (`file.h`). This mounting is taking place at the first user process (`init.c`). The result of this mounting is that every time the kernel tries to read/write from "/proc" file it uses a function provided by the device (`procfs.c`) instead of performing operations on the disk.

Your assignment is to implement an interface provided by struct devsw (`file.h`) in order to create procfs. In order to "make your life easier" we provided procfs.c source file that describes the PROCFS device.

- ***int procfsisdir(struct inode *ip)***
  The function returns zero if the file represented by ip is not a directory and a non-zero value otherwise
- ***void procfsiread(struct inode* dp, struct inode *ip)***
  The function receives ip (with initialized ip->inum) and initialized dp that represents ip's parent directory. This function can update all ip fields. Note that if ip->flags does not contain the I_VALID flag the inode will be read from the disk (since all files in procfs are "virtual", they will not reside on the disk).
- ***int procfsread(struct inode *ip, char *dst, int off, int n)***
- ***int procfswrite(struct inode *ip, char *buf, int n)***
  These functions must implement read/write operations from the file represented by ip.

- You are not bound to this specific implementation of procfs (using a device). You are allowed to implement it however you want (you can revert our changes).

Under the /proc directory there should be a numerical subdirectory for each running process, the subdirectory is named by the process ID. Each such subdirectory should contain the following pseudo-files and directories:

/proc/PID/cmdline

The content of the file should be the command that originally started the process. Note that currently this data is not stored by the kernel. In order to support this functionality you need to maintain it in the kernel.

/proc/PID/cwd

This file should be a link to the current working directory of the process. Note that “cd cwd” must change the current working directory to cwd.

/proc/PID/exe

This file should be a link to the executable file whose execution created this process. Note that like in case of cmdline this data is not stored.

/proc/PID/fdinfo

A directory containing a file for each open file descriptor. Each file name (in the “fdinfo” directory) must be the file descriptor number. The file content must include the file's type, position (offset) and flags (read/write).

/proc/PID/status

The content of this file must include the process' run state and its memory usage (proc->sz).

- You must implement the procfs as a read-only file system.
- Since the OS has a dynamic nature (processes and files may be “created” and “destroyed”), procfs may present partially incorrect information. In the current assignment you are not required to deal with these situations (and they will not be checked).
- For this assignment you should download xv6 code form: http://www.cs.bgu.ac.il/~osce161/git/assignment4.git

Enjoy!