OPERATING SYSTEMS: FILE SYSTEMS

Files, directories and file system

To remember…

Alejandro Calderón Mateos

Before classes	Class	After class

Prepare the prerequisites.

Study the material associated with the **bibliography**:
slides alone are not enough.
Please ask questions (especially after study).

Exercising skills:

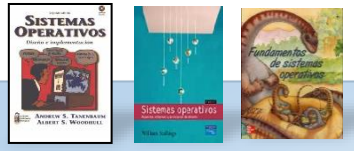
- Perform all **exercises**.
- Carrying out the **practice notebooks** and **the practical exercises** progressively.

Recommended reading

Base

1. Carretero 2020:
   1. Cap. 6
2. Carretero 2007:
   1. Cap. 9.1-9.5,
   2. Cap. 9.8-9.10 & 9.12

Suggested



1. Tanenbaum 2006:
   1. (es) Cap. 6
   2. (en) Cap. 6
2. Stallings 2005:
   1. 12.1-12.8
3. Silberschatz 2006:
   1. 10.3-10.4,
   2. 11.1-11.6 and 13

Contents

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- Introduction
- File
- Directory
- File System
- Partitions/Volumes
- Devices
- System software
- File System (manager)

Contents

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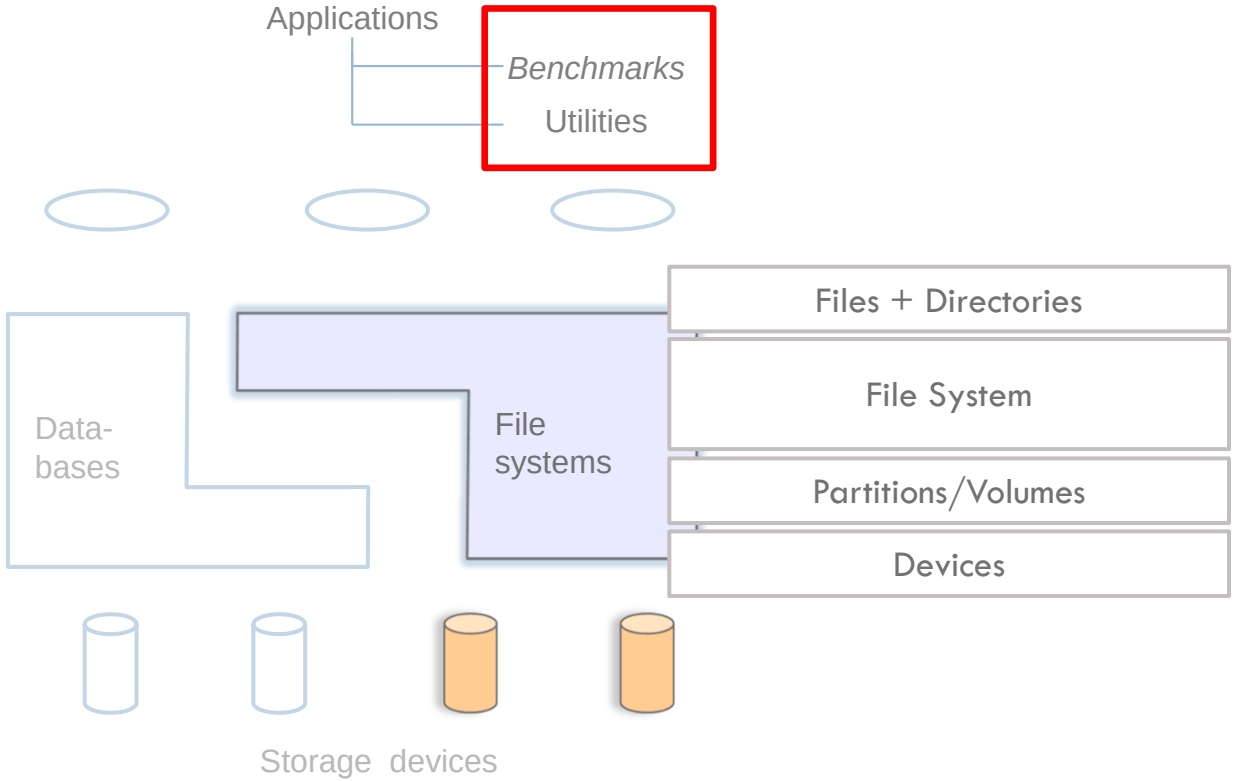
System software



Benchmarks

- Benchmarks:
  - They allow to measure the performance of the file system (and any dependency on it)
  - Designed to measure different aspects:
    latency, bandwidth,
    number of files processed per unit time, etc.
  - Examples working with metadata: fdtree, mdtest, etc.
  - Examples working with data: iozone, postmark, IOR, etc.

File system consistency

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- Software failures may result in inconsistent information (and metadata).
- Solution:
  - Availability of tools to check the file system and repair the errors found.
- Two important aspects to review:
  - Verify that the physical structure of the file system is coherent
  - Verify that the logical structure of the file system is correct.

File system consistency

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File system consistency

physical structure

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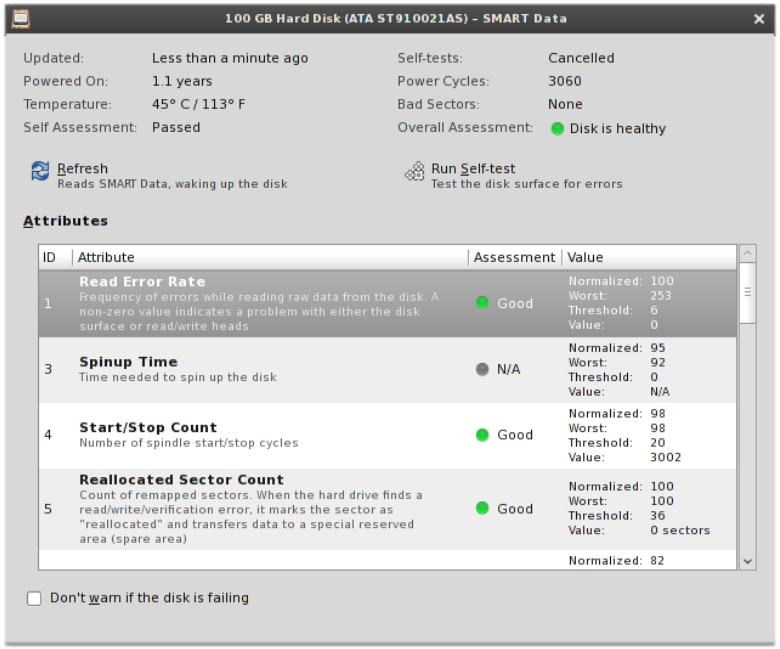
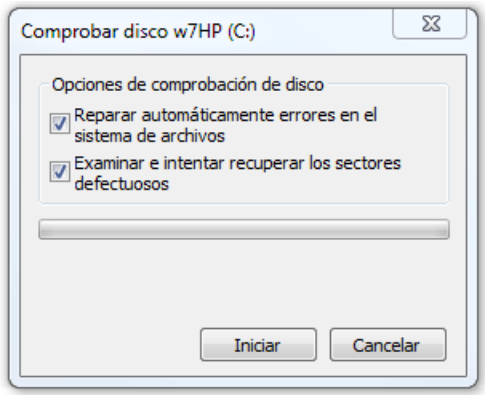
- Controller logic:
  - Disk-controller status tests are performed.
  - E.g.: S.M.A.R.T.



- Disk surface:
  - Reads/writes disk blocks one by one to check for problems on the surface of part of the disk.
  - E.g.: if what is read is different from what is written



File system consistency

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- Solution:
  - Availability of tools to check the file system and repair the errors found.
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File system consistency

logical structure

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- Disk structures:
  - Check that the data structure on disk is consistent for partition, directories and files
  - E.g.: fsck in Linux, scandisk in Windows

```
acaldero@phoenix:/tmp$ sudo fsck -f /dev/loop1
fsck desde util-linux-ng 2.17.2
e2fsck 1.41.12 (17-May-2010)
Paso 1: Verificando nodos-i, bloques y tamaÃ±os
Paso 2: Verificando la estructura de directorios
Paso 3: Revisando la conectividad de directorios
Paso 4: Revisando las cuentas de referencia
Paso 5: Revisando el resumen de informaciÃ³n de grupos
/dev/loop1: 11/28560 ficheros (0.0% no contiguos), 5161/114180 bloques
acaldero@phoenix:/tmp$
```

File system consistency

logical structure

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- File System on disk:
  - Check that the content of the superblock corresponds to the characteristics of the file system.
  - It is checked that the i-node bitmaps correspond to the occupied i-nodes in the file system.
  - Check that the bitmaps of blocks correspond to the blocks assigned to files.
  - Check that no block is assigned to more than one file.
- Directories:
  - The directory system of the file system is checked to see that the same node-i is not assigned to more than one directory.
- Files:
  - The protection and privilege bits are checked.
  - The link counter is checked.

Backup

Where?

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- Place:
  - Distant from the main system
  - Protected from water, fire, etc.
    - Fireproof cabinets

- Medium:
  - Hard disk
    - A: capacity and price, D: fragile
  - Tape
    - A: capacity and price, D: slow

Backup

How?

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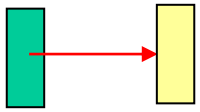
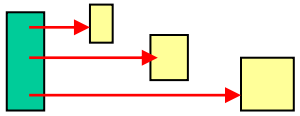
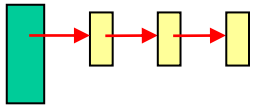
- Full backup:
  copy the entire contents of the file system.



- Differential backup:
  contains all files that have been changed since the last **full backup**.



- Incremental backup:
  contains all files that have been modified since the last **full backup** or **differential backup**



Backup

When?

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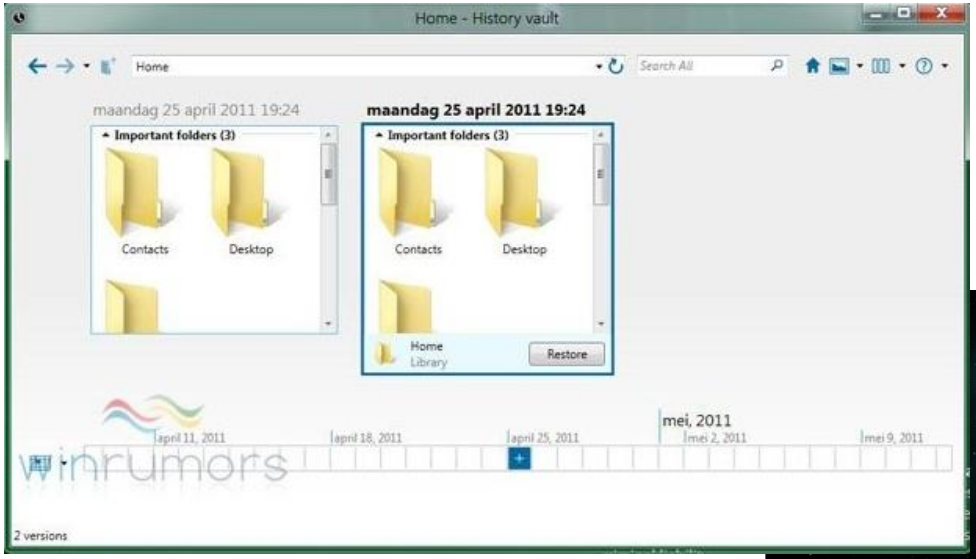
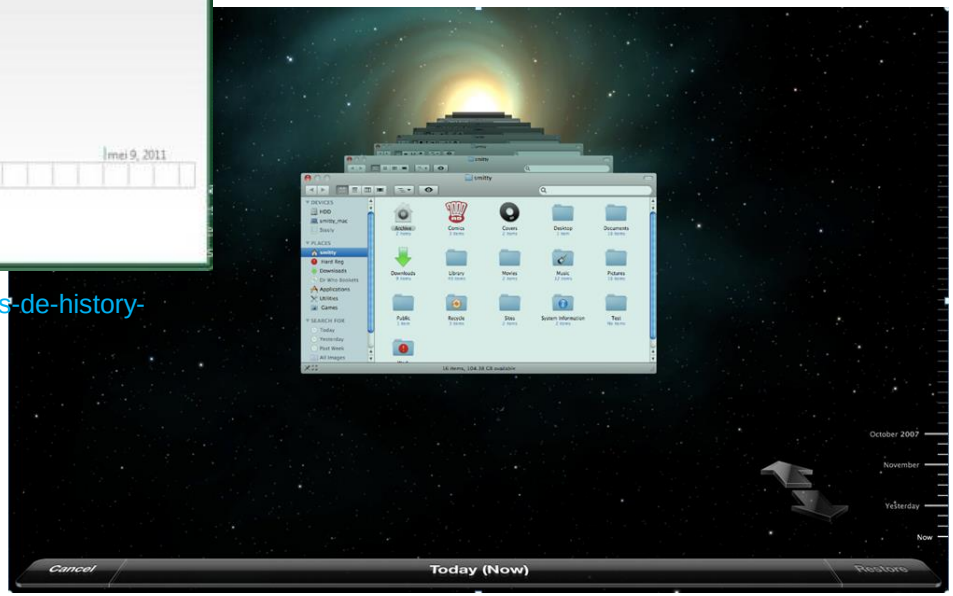
- Off-line:
  - The backup is performed during periods of time when the system data is not in use.
- On-line:
  - The backup is performed while the system is in use.
  - Use of techniques to avoid consistency problems:
    - *Snapshots*
      read-only copy of the file system state.
    - *Copy-on-write*
      writes after snapshot are performed in copies.

Backup copy



http://www.genbeta.com/systems-operativos/primeras-imagenes-de-history-vault-el-time-machine-de-windows-8



http://www.reghardware.com/2007/11/08/review_leopard_pt2/page2.html

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- System software
- **File System (manager)**

File management architecture...

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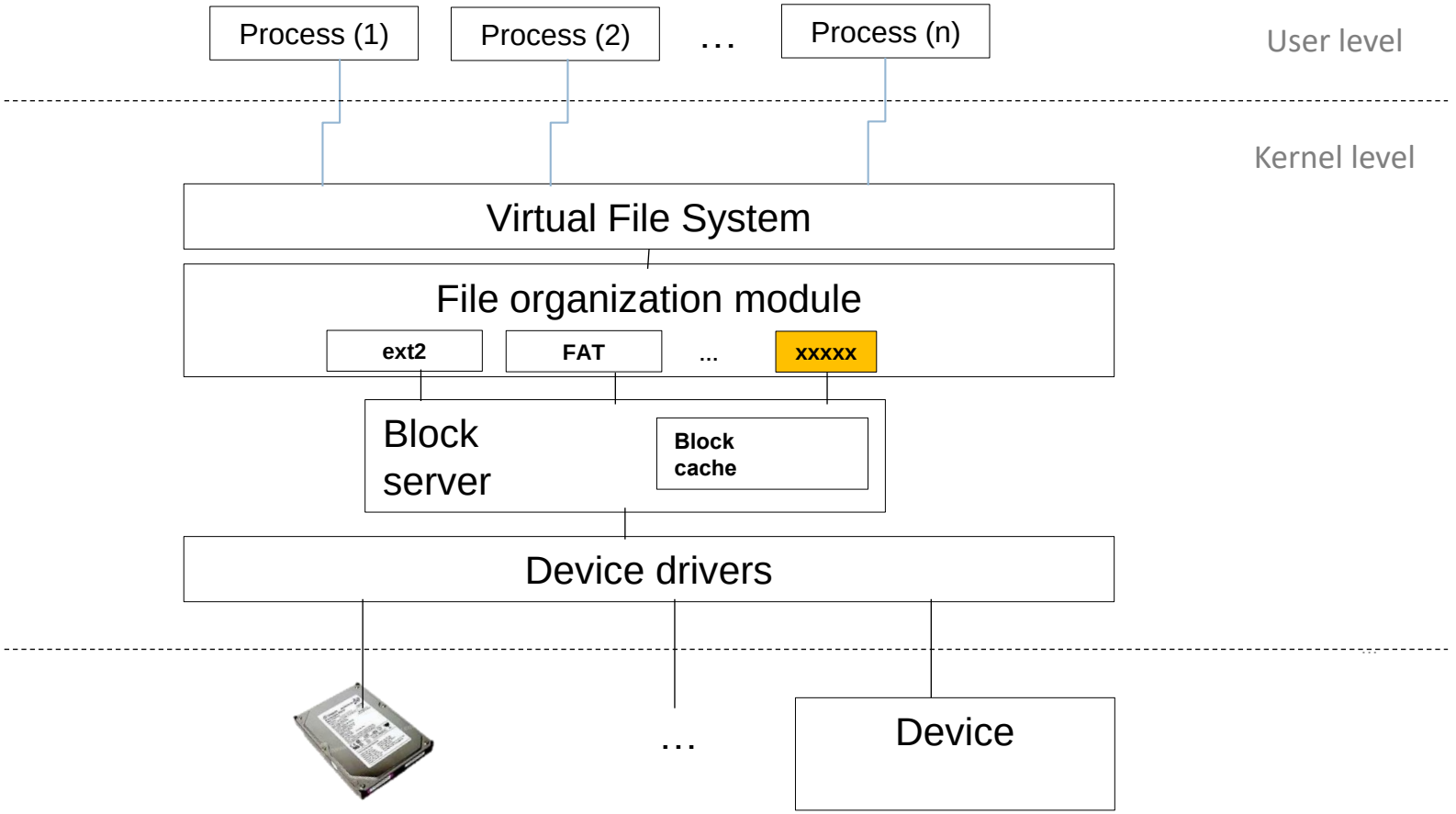
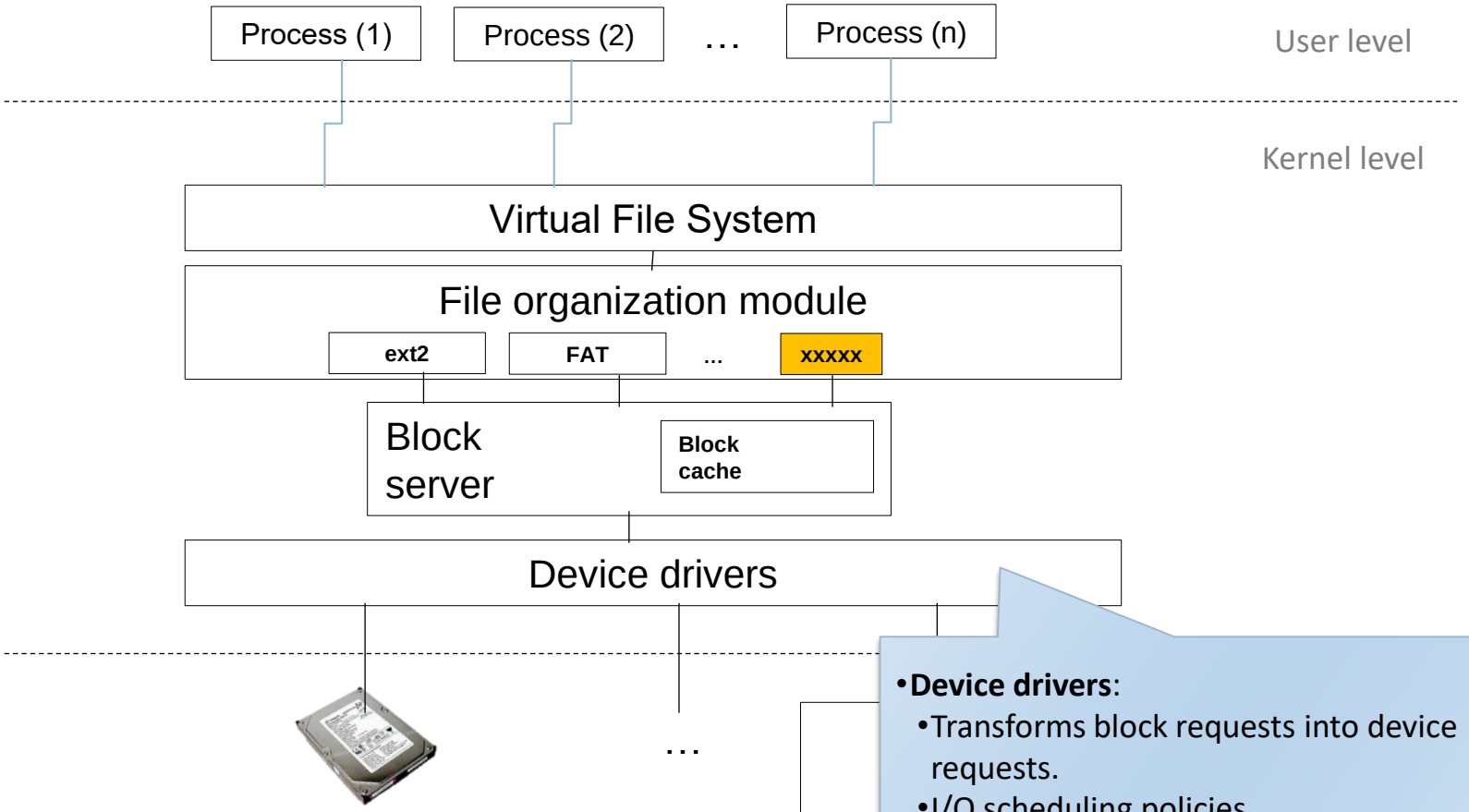


File management architecture…



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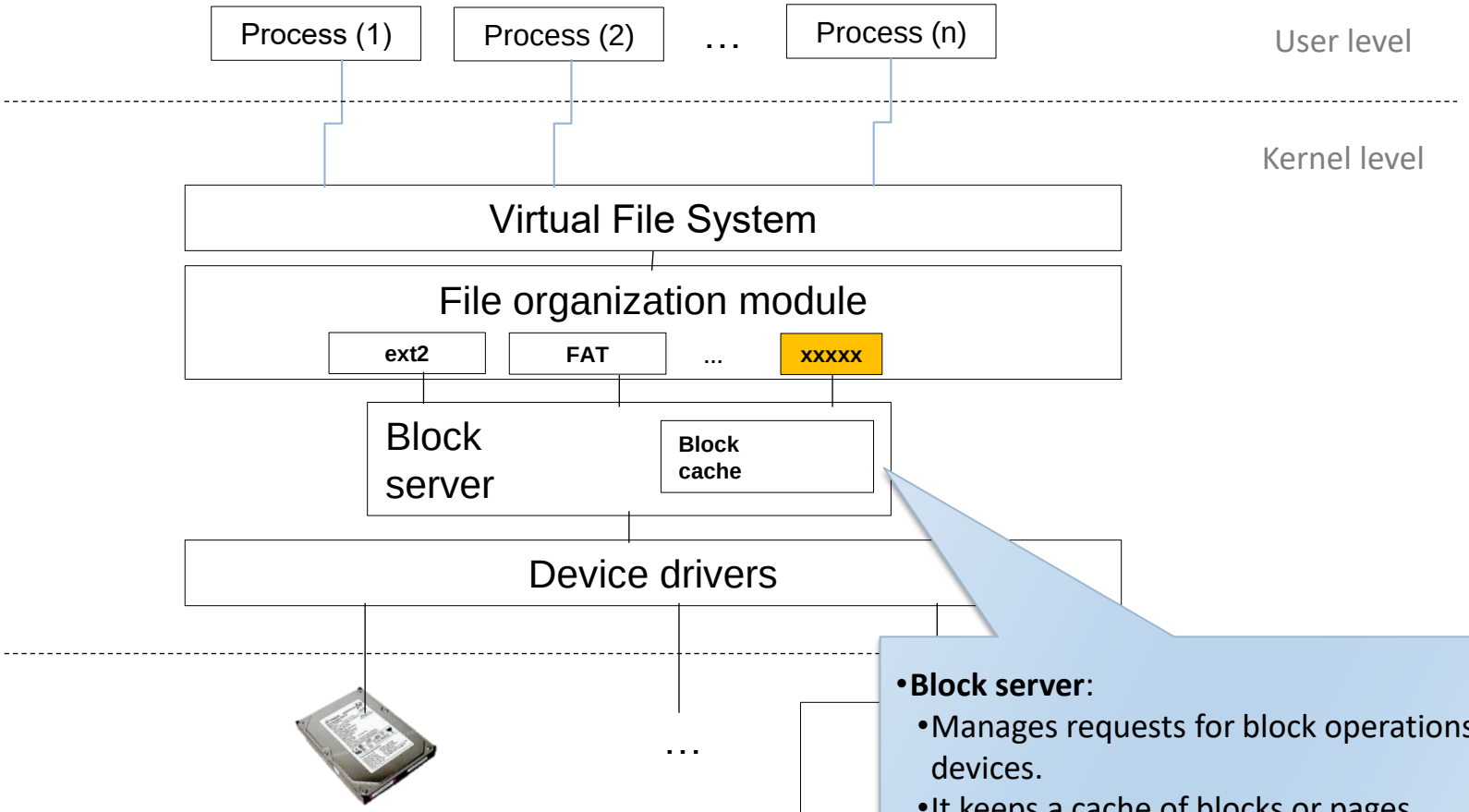

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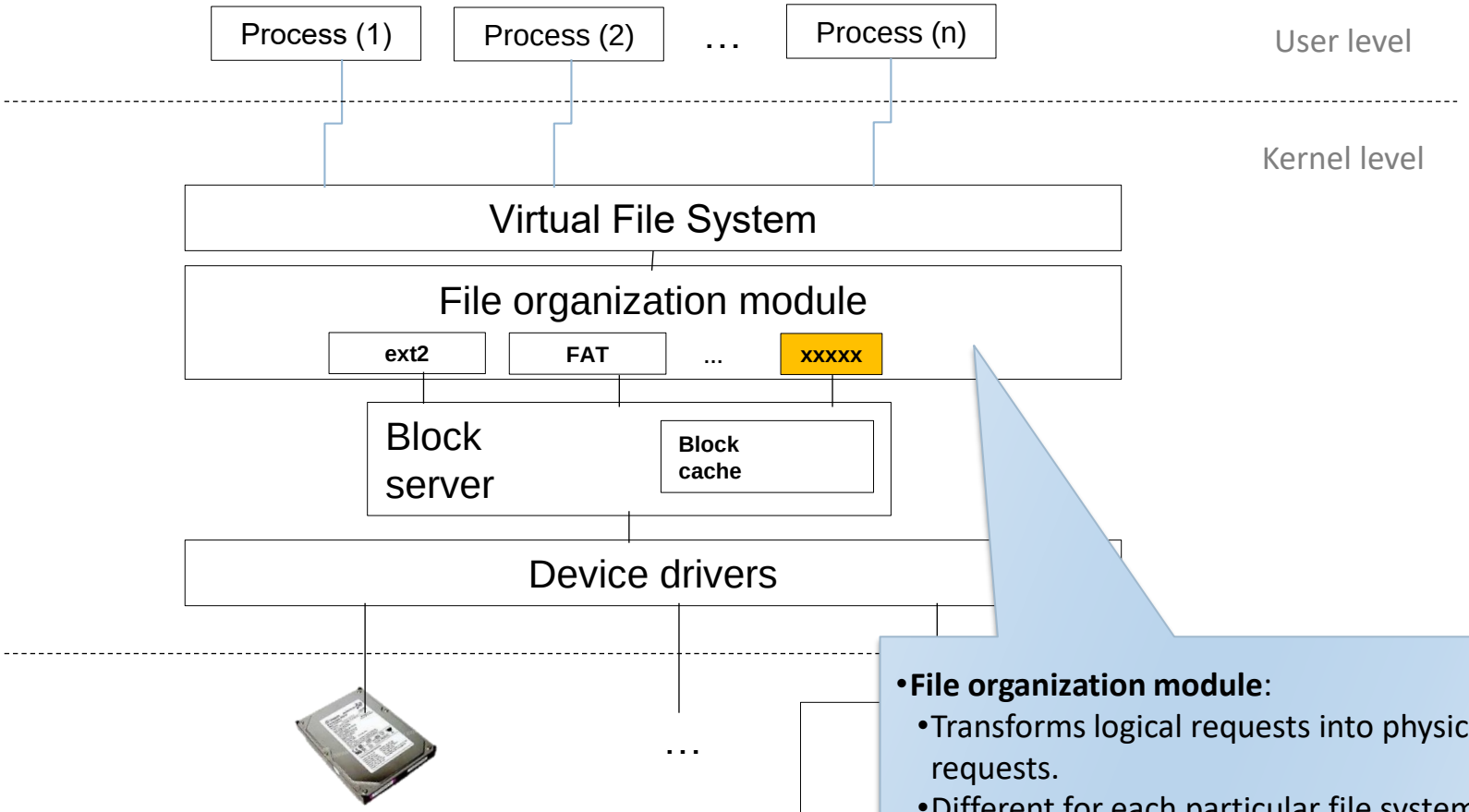
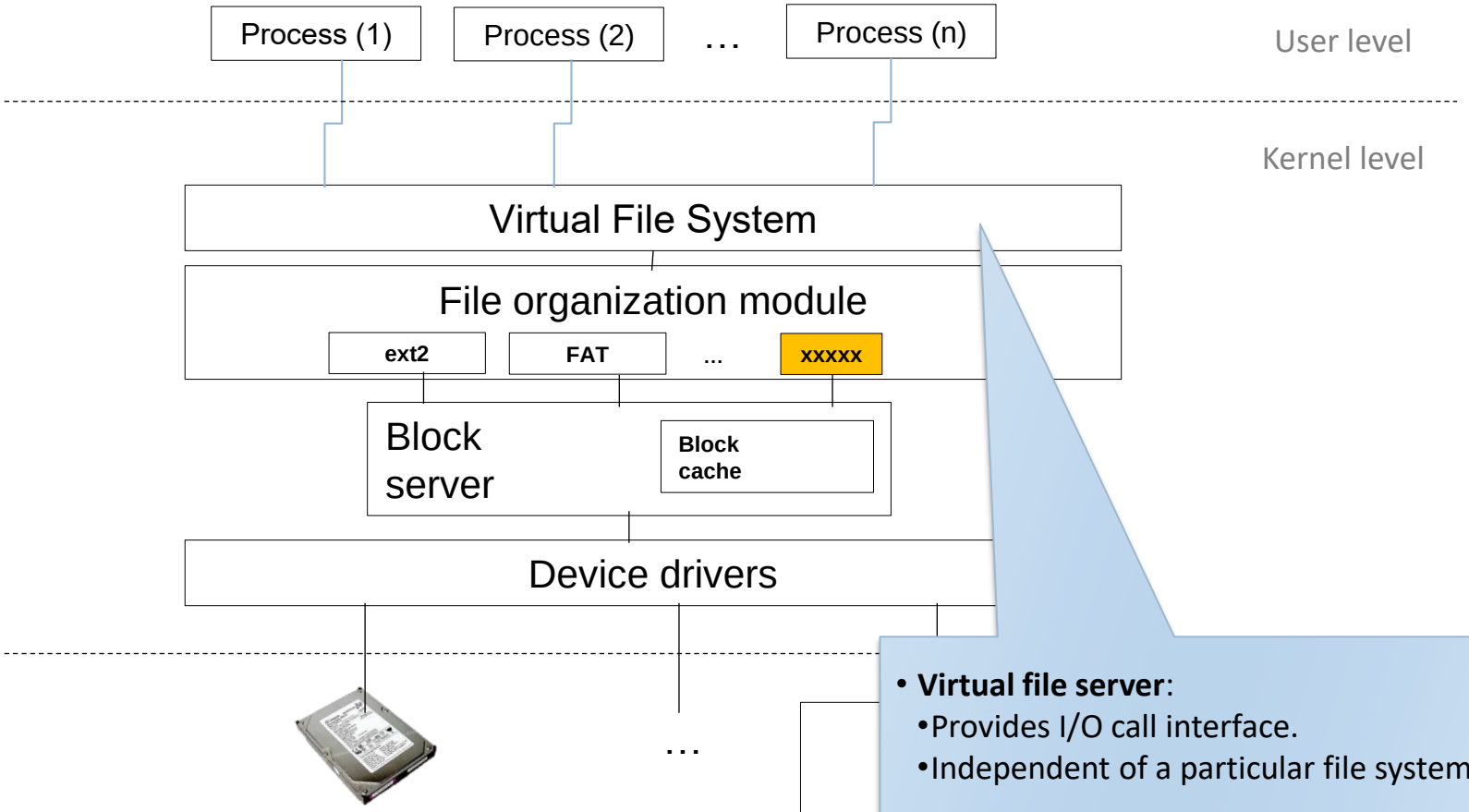


File management architecture…



Destination (related to architecture)…
file system design and implementation

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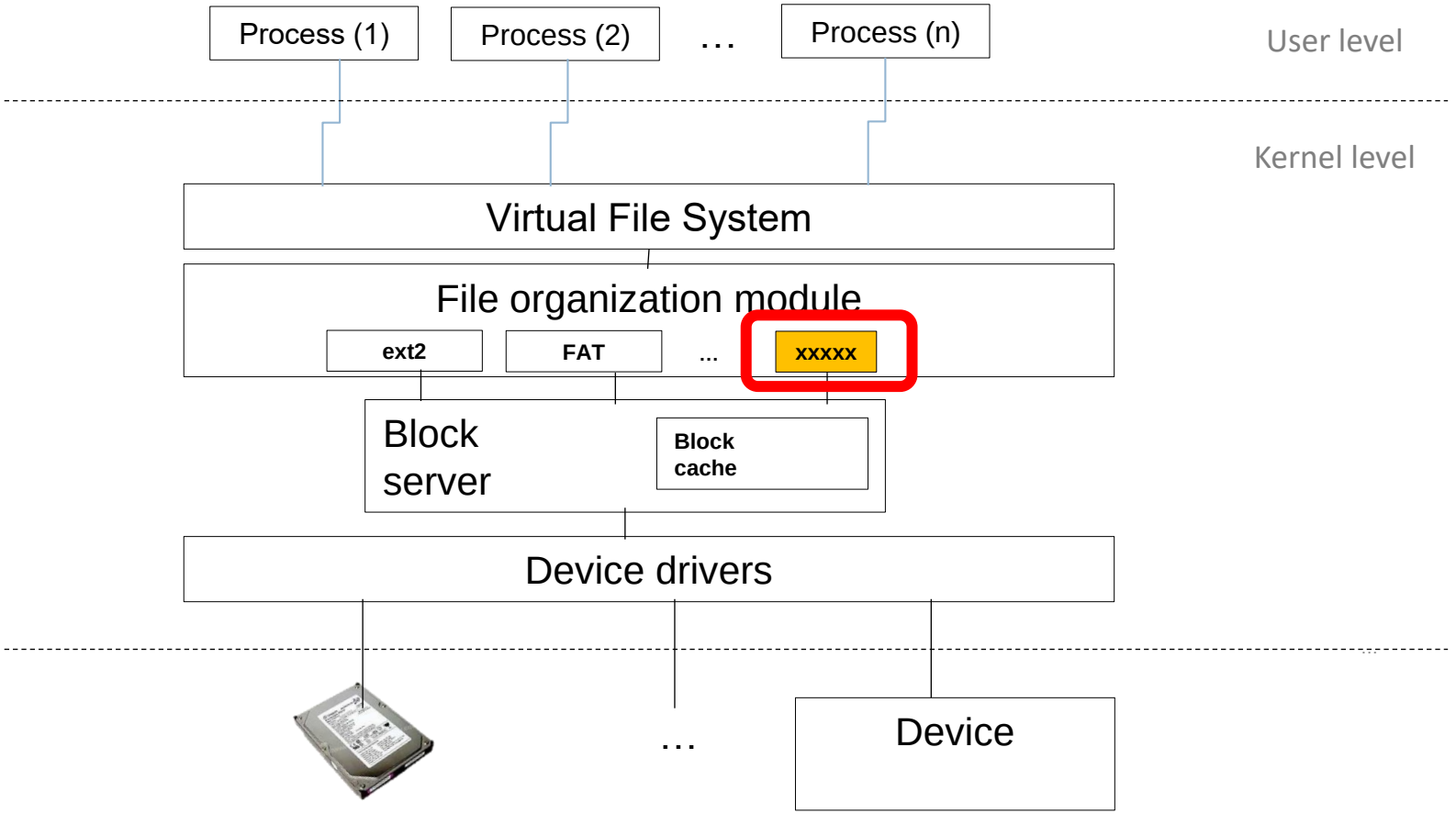

Origin (related to architecture)…
a) disk blocks + b) disk block cache

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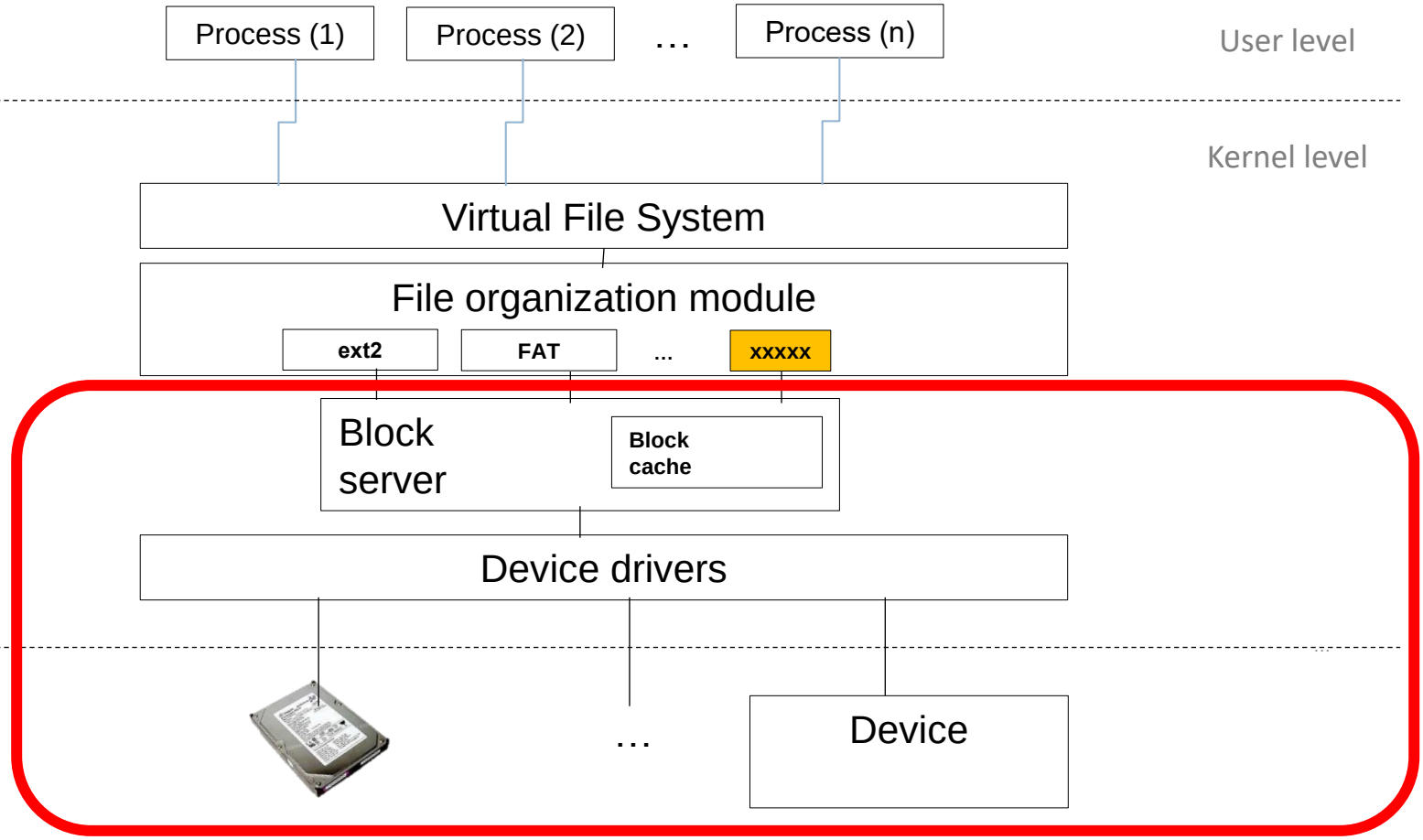

Origin (related to architecture)…
a) disk blocks

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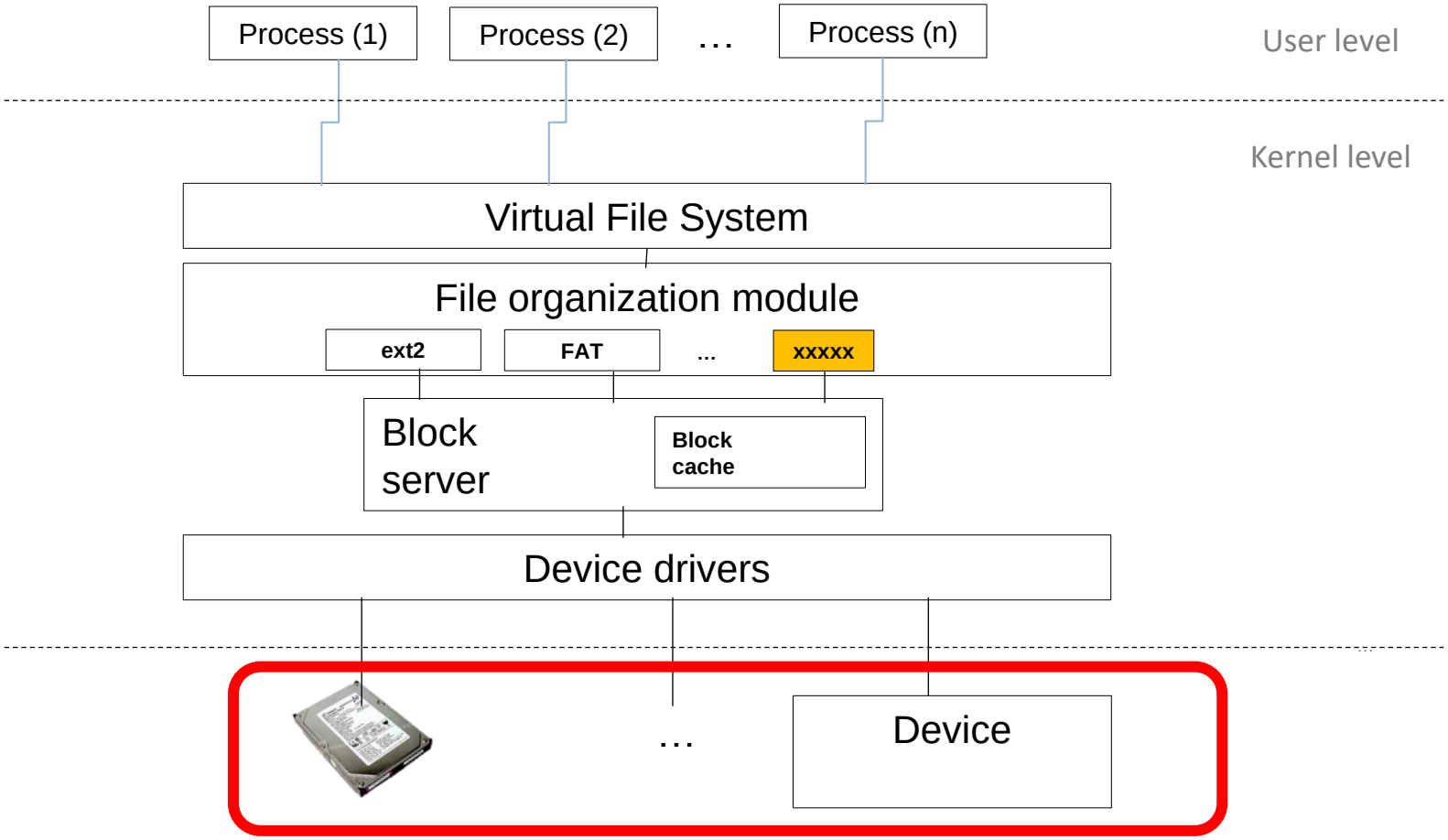

Origin (related to architecture)…
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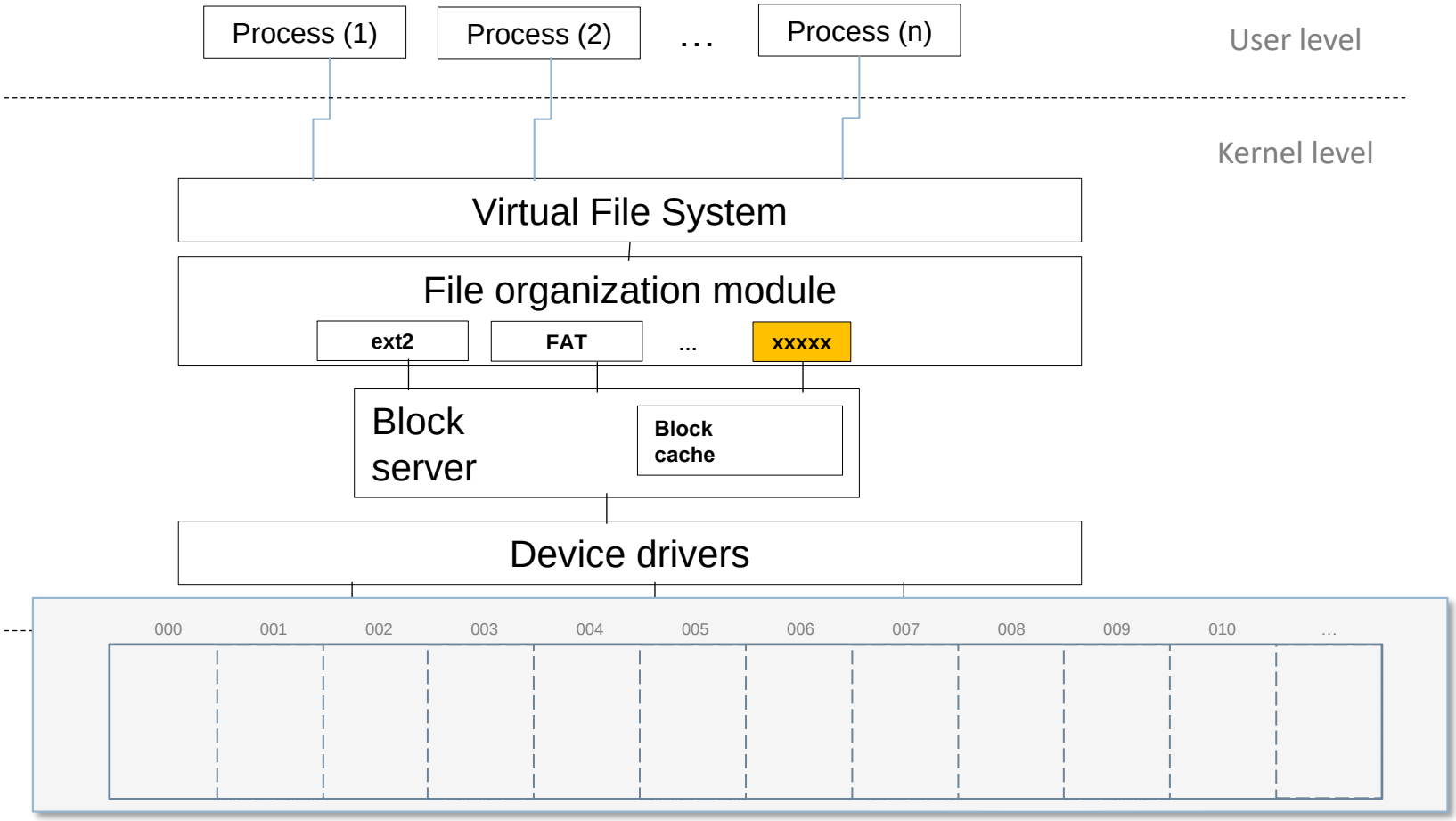

Origin (related to architecture)…
b) disk block cache

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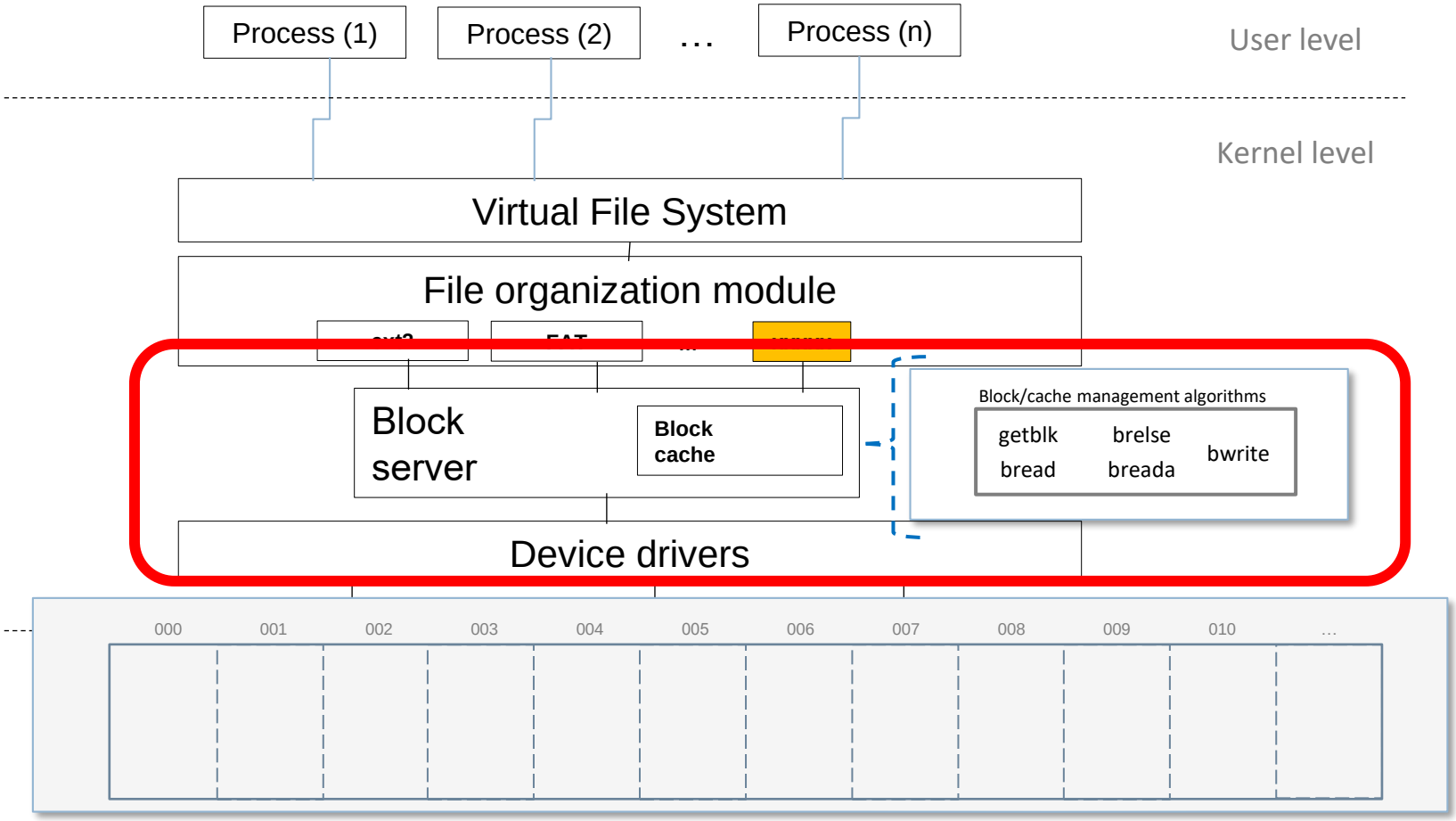
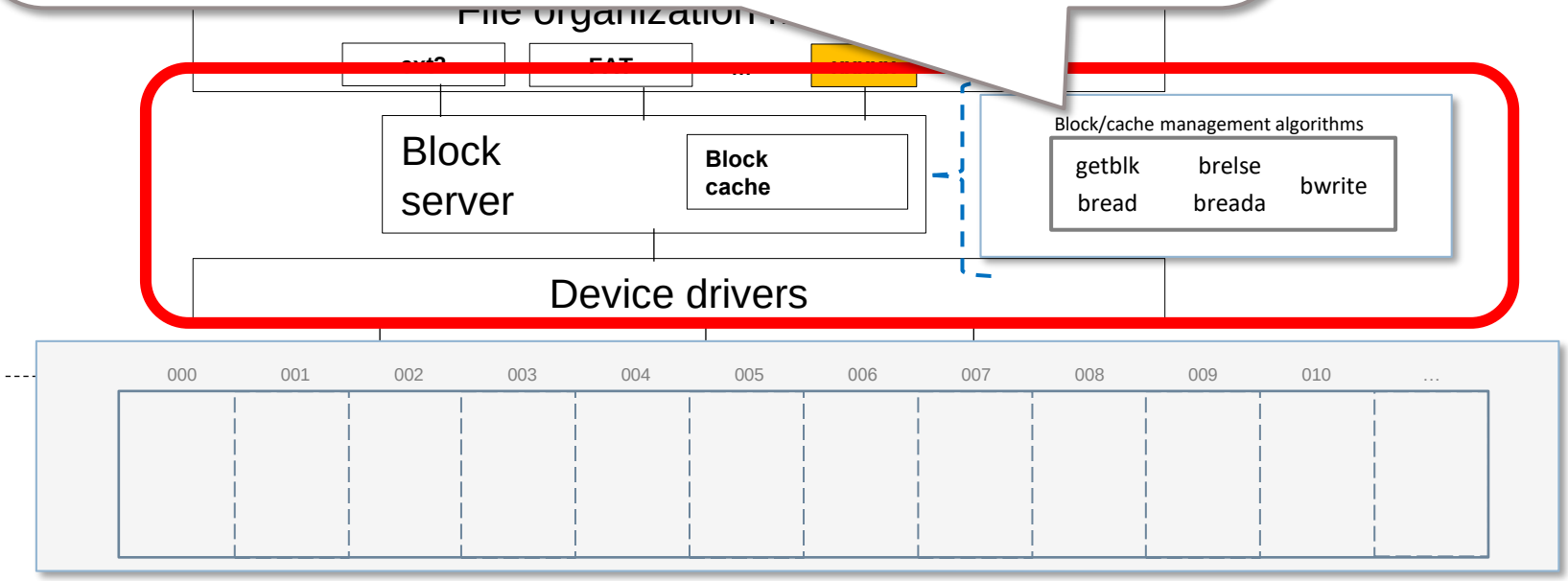


Origin (related to architecture)…
b) disk block cache

- **getblk**: searchs/allocates a block in cache (from a given v-node, offset and size).
- **brelse**: releases a block and adds it to the free list.
- **bwrite**: writes a cache block to disk.
- **bread**: reads a block from disk to cache.
- **breada**: reads 1 block (and the next) from disk to cache.



Block server

- It is in charge of:
  - Issue generic commands to read and write blocks to device handlers (using the device-specific routines).
  - Optimize I/O requests.
    - Ej.: block cache.
    - Can be integrated with virtual memory manager.
  - Provide a logical naming for the devices.
    - E.g.: /dev/hda3 (third partition of the first disk)

Block server

- General operation:
  - If the block is in cache
    - Copy content (+ update block usage metadata)
  - If the block is not in cache
    - Read the device block and store it in the cache
    - Copy content (and update metadata)
    - If the block has been written on (dirty)
      - Writing policy
    - If the cache is full, it is necessary to make room for it
      - Replacement policy

Block server

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- General operation:
  - **read-ahead**:
    - Read a number of blocks after the required one and cached (improves performance on consecutive accesses)
  - Read the device block and store it in the cache
  - Copy content (and update metadata)
  - If the block has been written on (dirty)
    - Writing policy
  - If the cache is full, it is necessary to make room for it
    - Replacement policy

Block server

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- **write-through:**
  - It is written each time the block is modified (– yield, + reliability)
- **write-back:**
  - Data are only written to disk when they are chosen for replacement due to lack of cache space (+ performance, – reliability)
- **delayed-write:**
  - Write to disk the modified data blocks in the cache periodically every certain time (30 seconds in UNIX) (compromise between previous)
- **write-on-close:**
  - When a file is closed, its blocks are dumped to disk..

- If the [illegible]been written on (dirty)
  - Writing policy
- If the cache is full, it is necessary to make room for it
  - Replacement policy

Block server

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- General operation:
  - If the block is in cache
    - Copy content (+ update block usage metadata)
  - If the block is not in cache
    - Read the device block and store it in the cache
    - If the cache is full, it is necessary to make room for it
      - Replacement policy

- **FIFO** *(First in First Out)*
- **Clock algorithm** *(Second opportunity)*
- **MRU** *(Most Recently Used)*
- **LRU** *(Least Recently Used)* <- + frequently used

Destination (related to architecture)…
file system design and implementation

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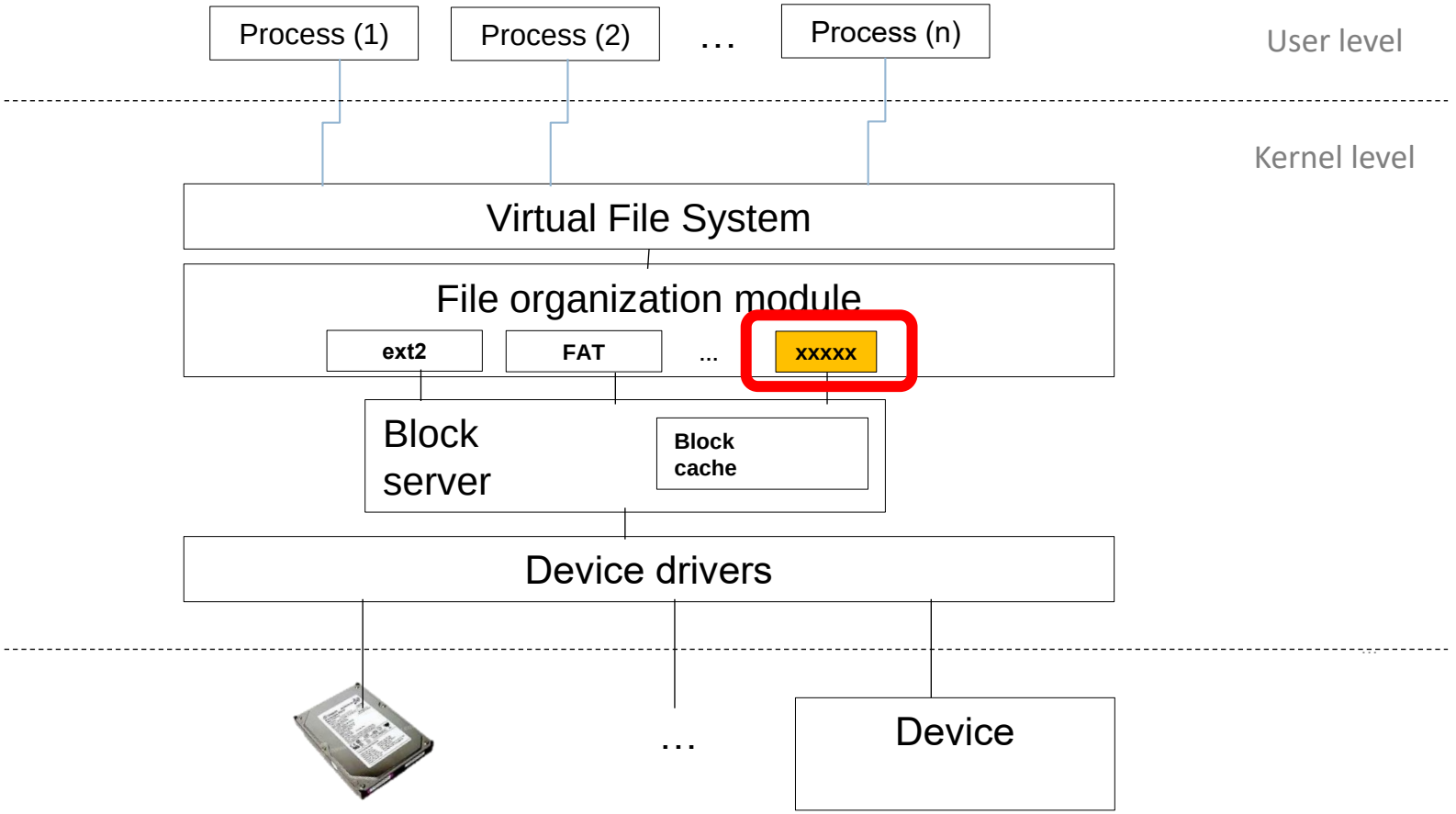

Aspects to be design (related to architecture)…
(1) Data structures on disk…

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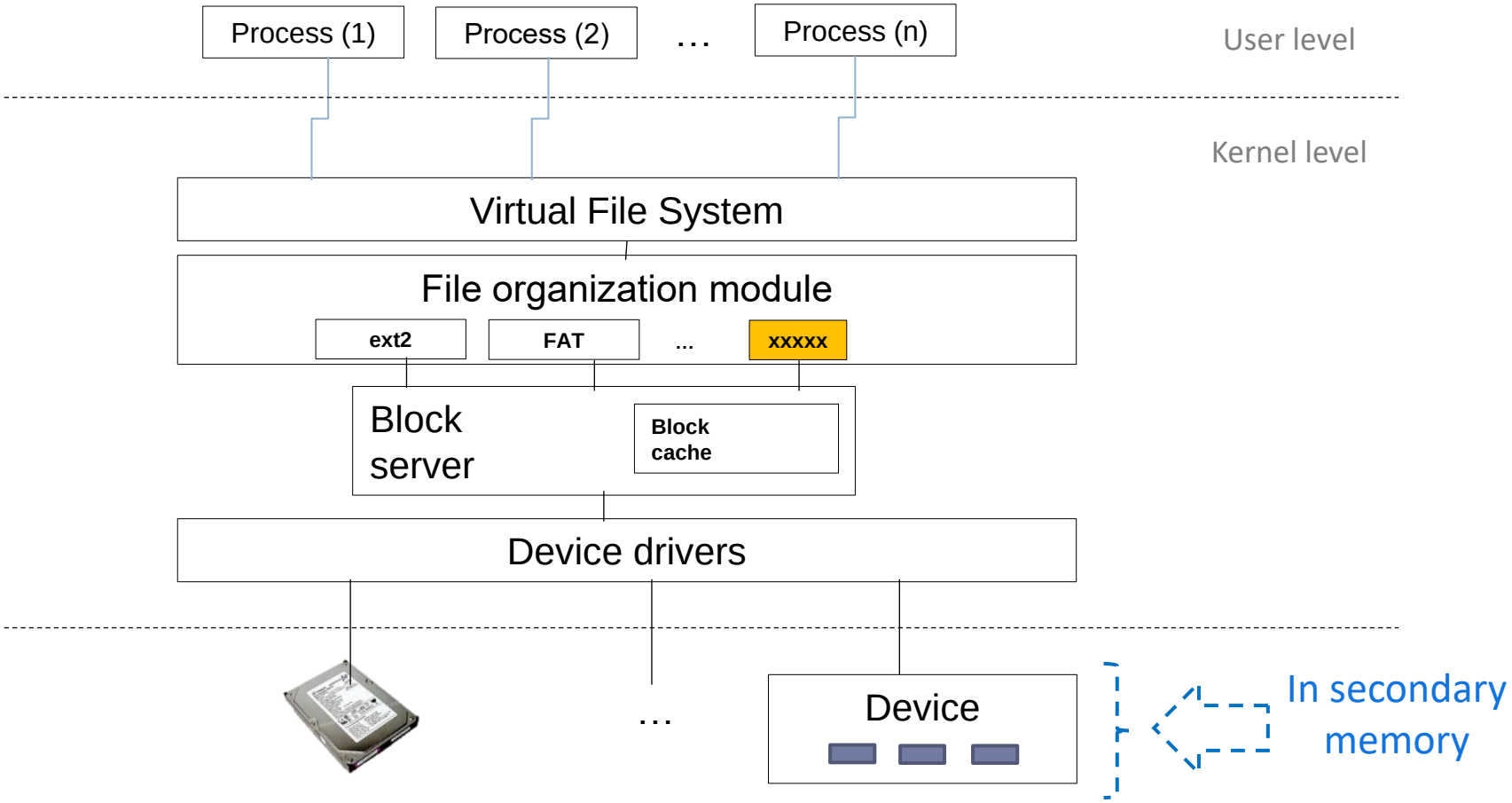

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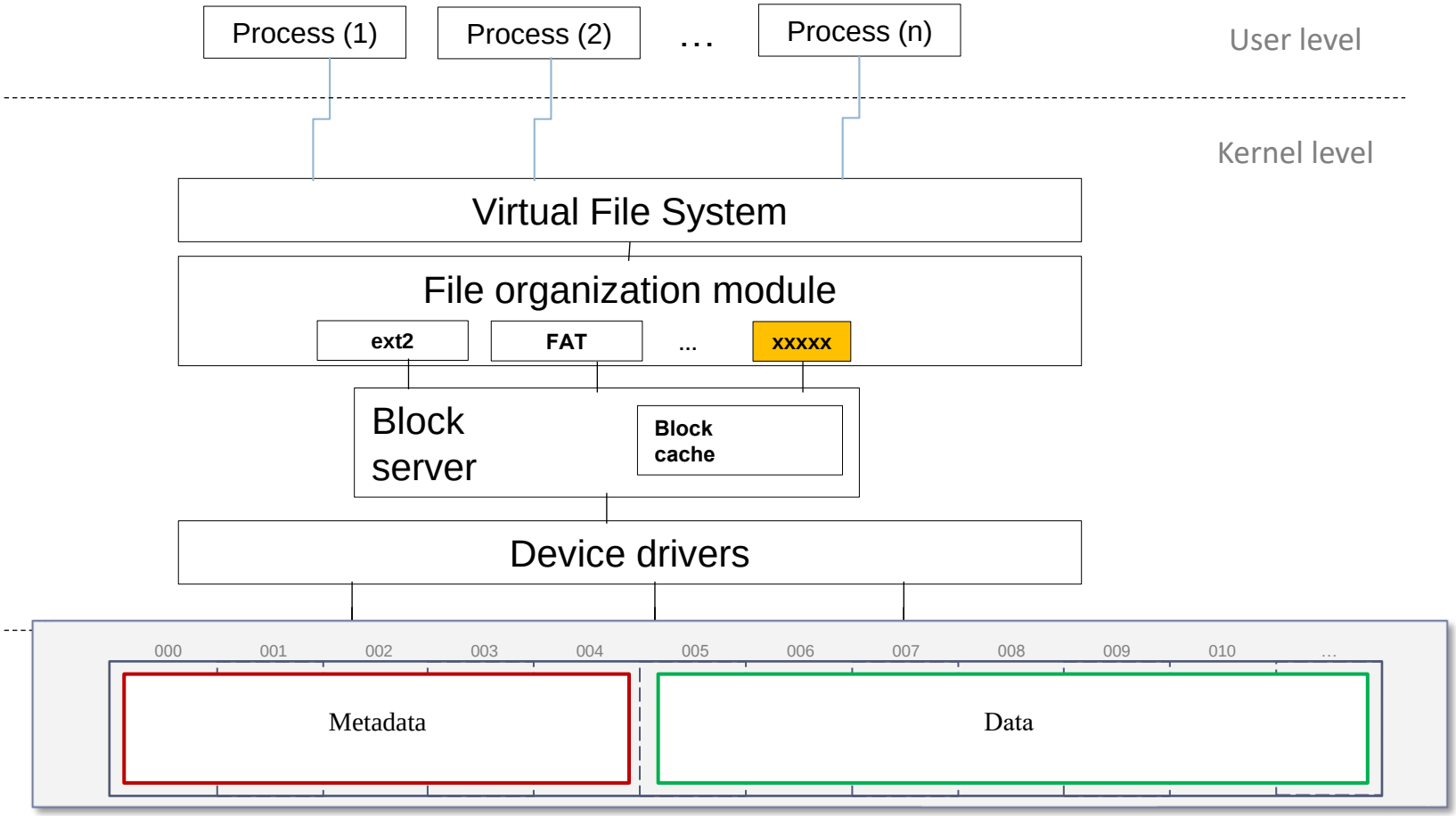

Aspects to be design (related to architecture)…
(2) Data structures in memory…

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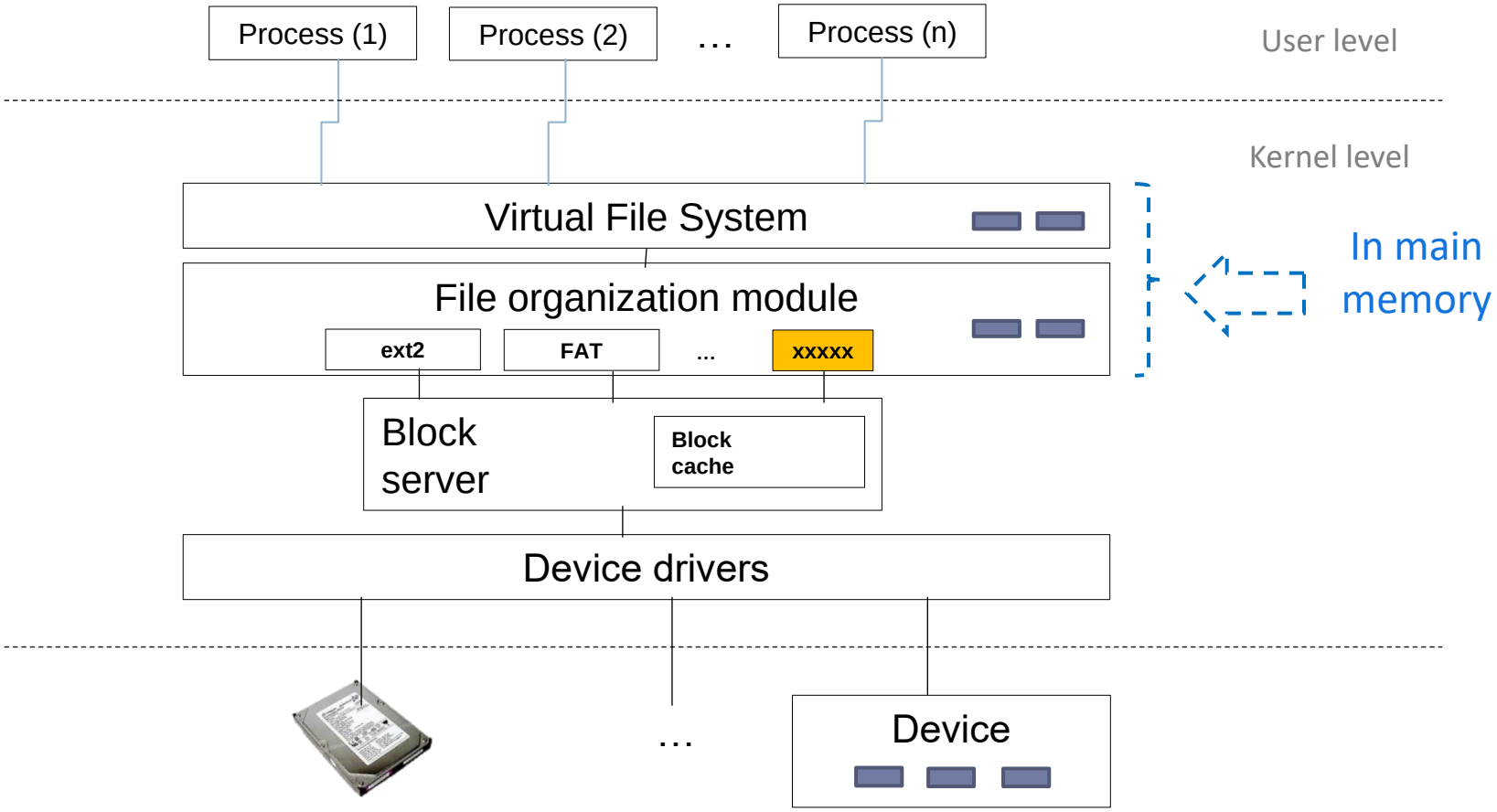

Aspects to be design (related to architecture)…
(3a) Management of disk/memory structures …

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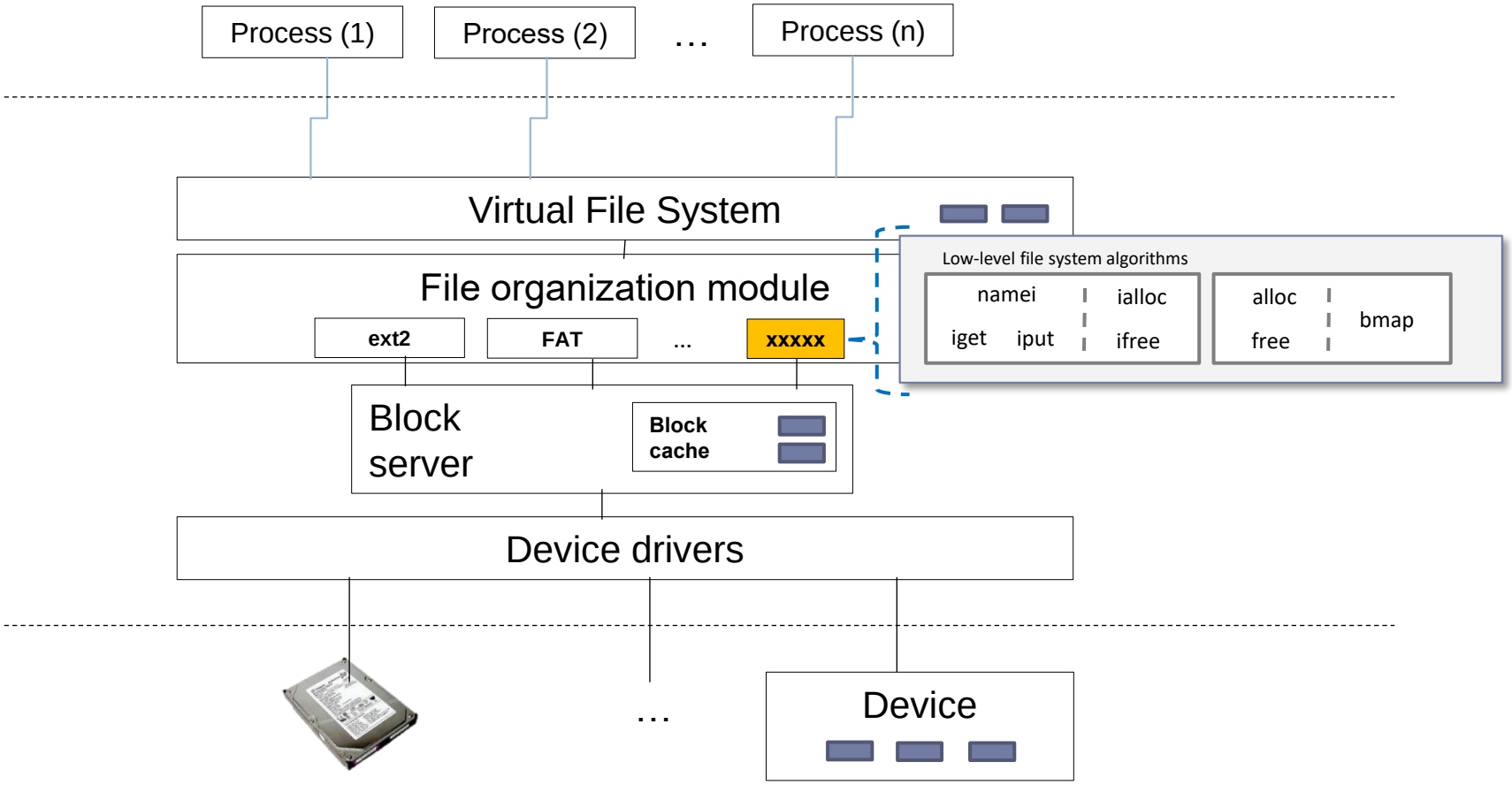
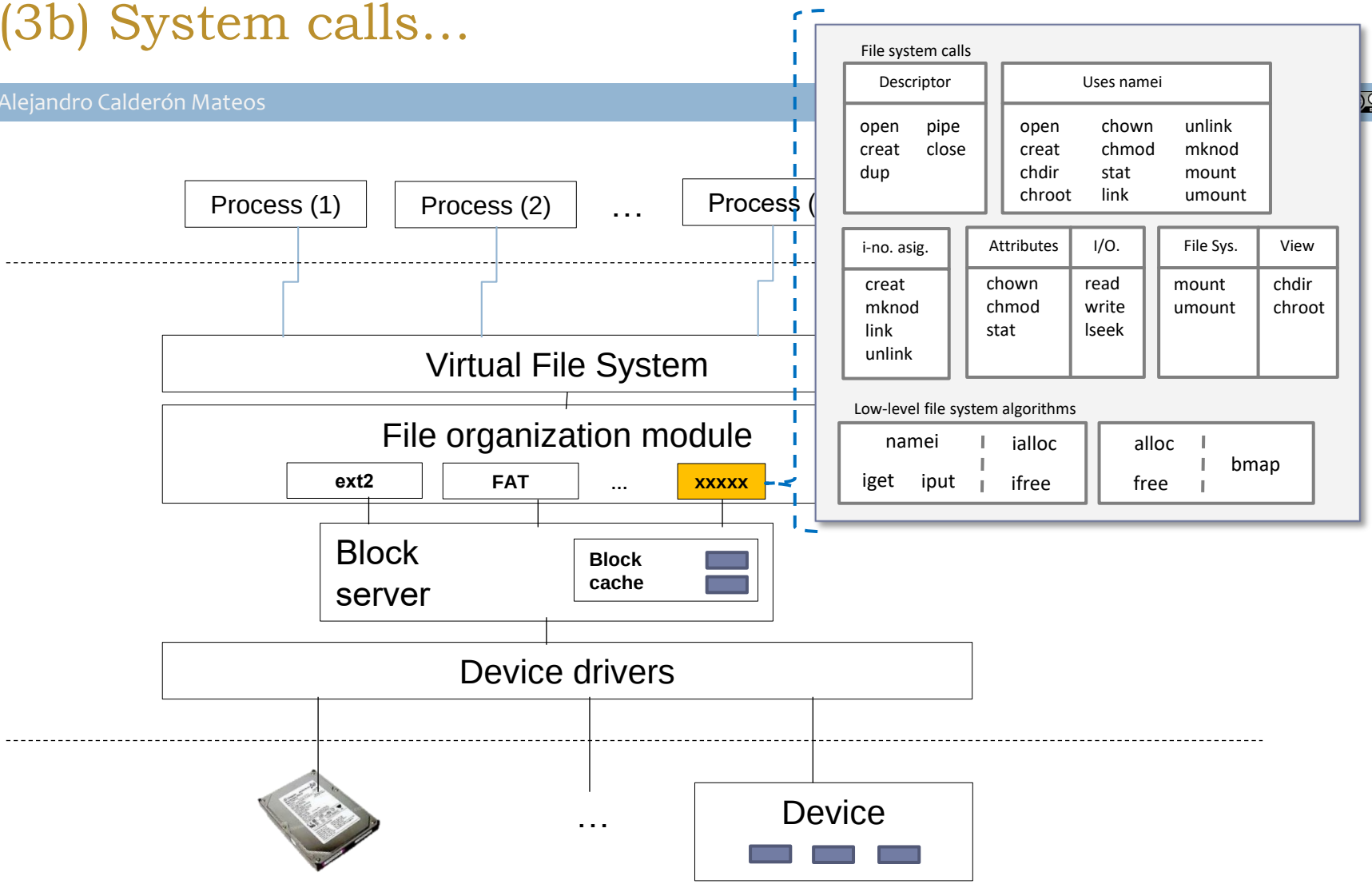
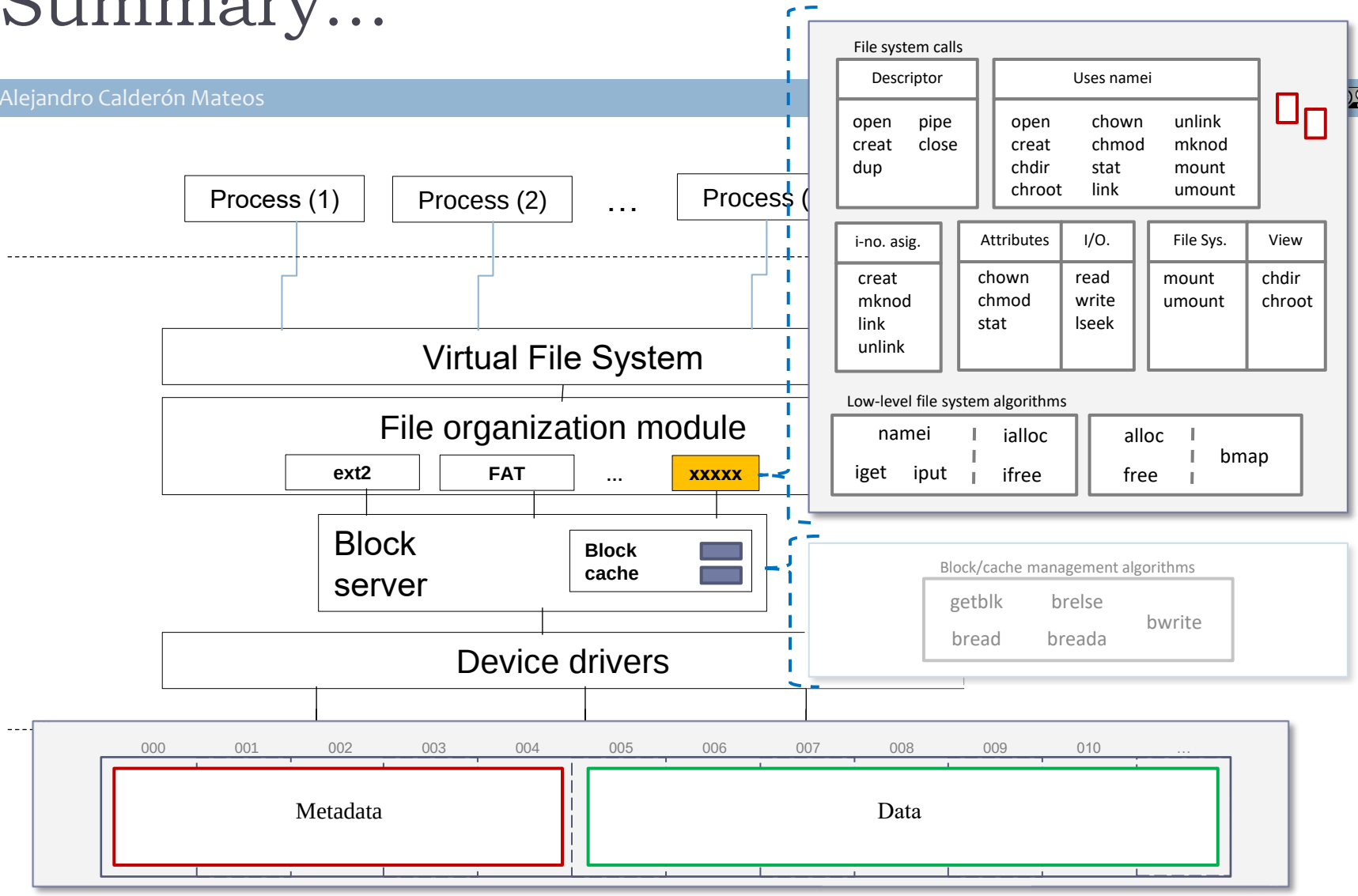


Aspects to be design (related to architecture)…
(3b) System calls…



Summary…


Process (1)
Process (2)
...
Process (
Virtual File System
File organization module
ext2
FAT
...
xxxxx
Block server
Block cache
Device drivers
000
001
002
003
004
005
006
007
008
009
010
...
Metadata
Data
File system calls
Descriptor
open
pipe
creat
close
dup
Uses namei
open
chown
unlink
creat
chmod
mknod
chdir
stat
mount
chroot
link
umount
i-no. asig.
creat
mknod
link
unlink
Attributes
chown
chmod
stat
I/O.
read
write
lseek
File Sys.
mount
umount
View
chdir
chroot
Low-level file system algorithms
namei
iget
iput
ialloc
ifree
alloc
free
bmap
Block/cache management algorithms
getblk
brelse
bread
breada
bwrite

Simplified summary…

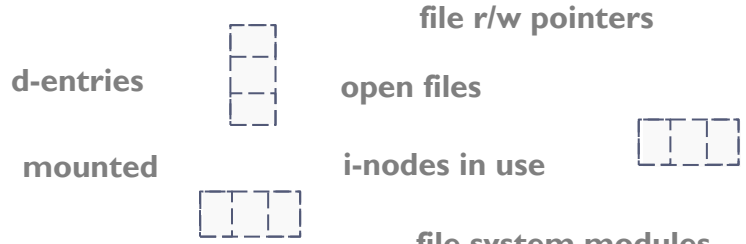
File system calls

Descriptor	Uses namei	i-no. asig.	Attributes	I/O.	File Sys.	View
open pipe creat close dup	open chown unlink creat chmod mknod chdir stat mount chroot link umount	creat mknod link unlink	chown chmod stat	read write lseek	mount umount	chdir chroot

xx

Low-level file system algorithms

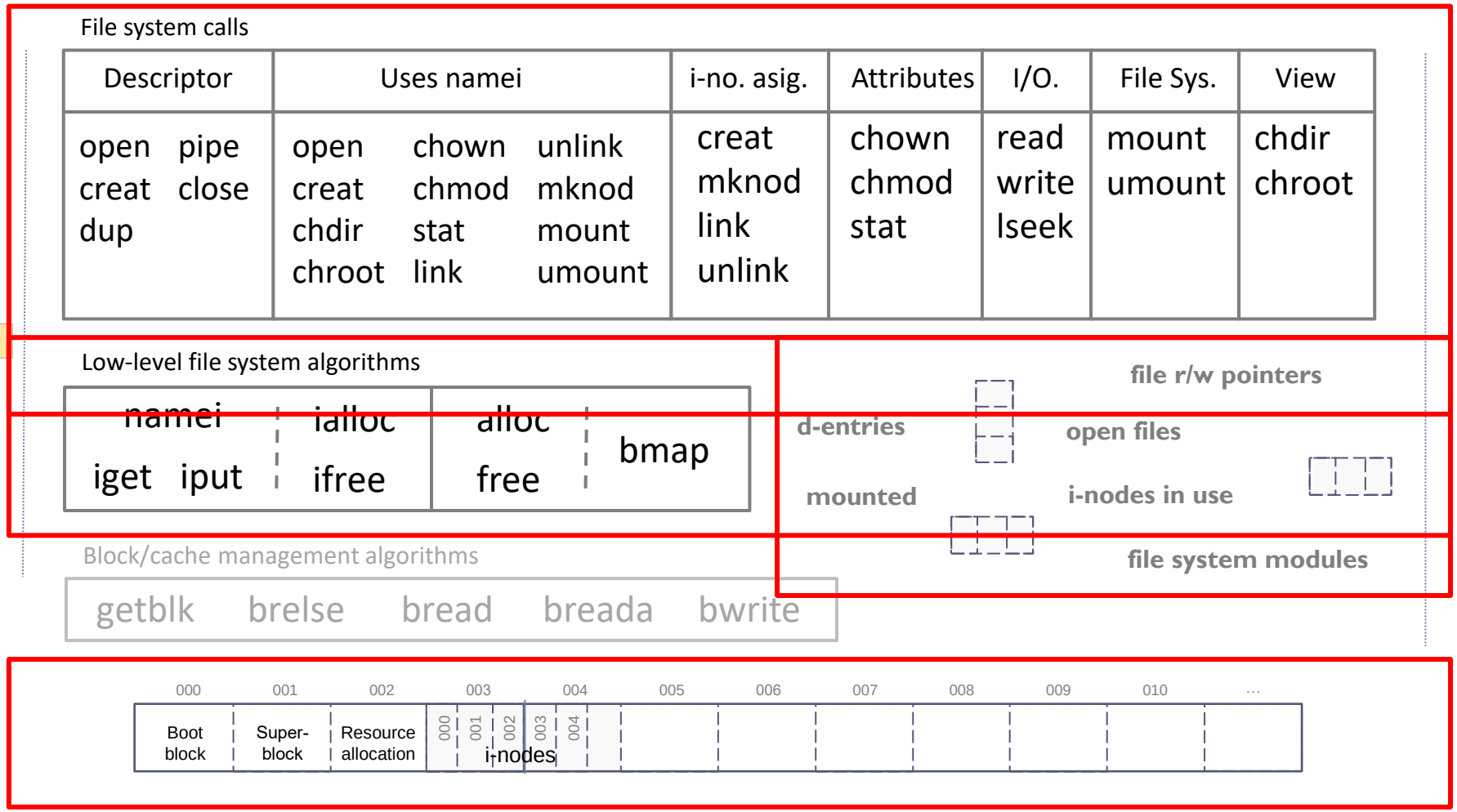
namei	ialloc	alloc	bmap
iget iput	ifree	free	



Block/cache management algorithms

getblk	brelse	bread	breada	bwrite

Elements to be analyzed (1, 2, 3a y 3b)



(1) Data structures on disk...

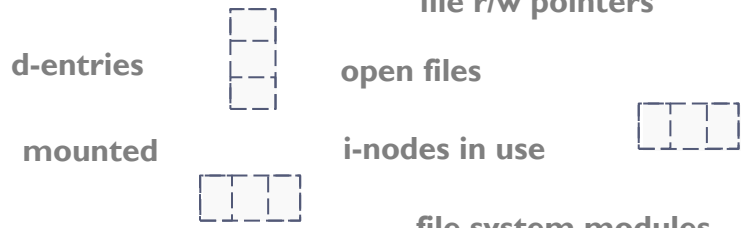
File system calls

Descriptor		Uses namei			i-no. asig.	Attributes	I/O.	File Sys.	View
open	pipe	open	chown	unlink	creat	chown	read	mount	chdir
creat	close	creat	chmod	mknod	mknod	chmod	write	umount	chroot
dup		chdir	stat	mount	link	stat	lseek		
		chroot	link	umount	unlink				

xx

Low-level file system algorithms

namei		ialloc	alloc		bmap
iget	iput	ifree	free		



Block/cache management algorithms

getblk	brelse	bread	breada	bwrite

Example of disk organization

https://github.com/acaldero/nanofs

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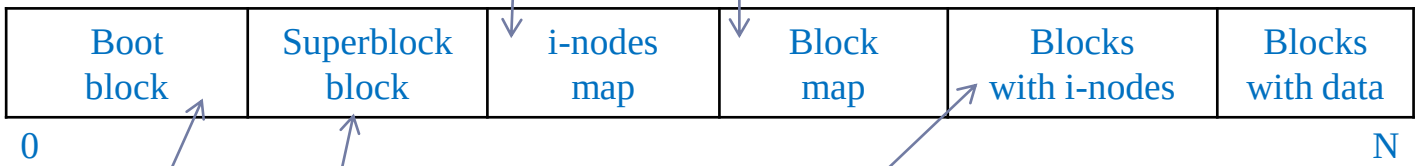
```
char imap[numInodes] ;     /* 100…0 (used: imap[x]=1 | free: imap[x]=0)
char bmap[numBlocksData] ;    /* 000…0 (used: bmap[x]=1 | free: bmap[x]=0)
```



000000…000

```
typedef struct {
   unsigned int numMagico;              /* Superblock magic number: 0x000D5500 */
   unsigned int numBlocksInodeMap;      /* Number of inodes map blocks */
   unsigned int numBlocksDataMap;       /* Number of data    map blocks */
   unsigned int numInodes;              /* Number of inodes in the device */
   unsigned int firstInode;             /* Index of the first block with inodes */
   unsigned int numBlocksData;          /* Number of data blocks in the device */
   unsigned int primerBloqueData;       /* Index of the first data block */
   unsigned int tamDevice;              /* Total device size (in bytes) */
   char padding[PADDING_SB];            /* Padding field to fill one block) */
} TypeSuperblock;
```

```
typedef struct {
   unsigned int type;                   /*  T_FILE o T_DIRECTORY */
   char nombre[200];                    /* Name of the associated file/directory */
   unsigned int inodosContents[200];    /* type==dir: list of directory inodes */
   unsigned int tamanyo;                /* Current file size in bytes */
   unsigned int blockDirecto;           /* Index of the direct block */
   unsigned int blockIndirecto;         /* Index of the indirect block */
   char padding[PADDING_INODO];         /* Padding field to fill one block */
} TypeDiskInode;
```

(2) Data structures on memory...

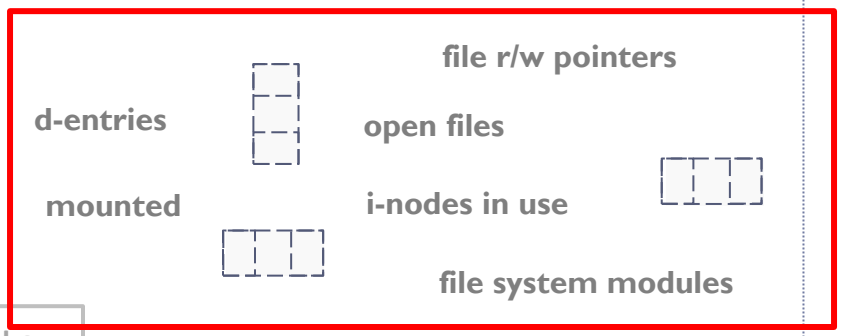
File system calls

Descriptor		Uses namei			i-no. asig.	Attributes	I/O.	File Sys.	View
open	pipe	open	chown	unlink	creat	chown	read	mount	chdir
creat	close	creat	chmod	mknod	mknod	chmod	write	umount	chroot
dup		chdir	stat	mount	link	stat	lseek		
		chroot	link	umount	unlink				

xx

Low-level file system algorithms

namei	ialloc	alloc	bmap
iget iput	ifree	free	

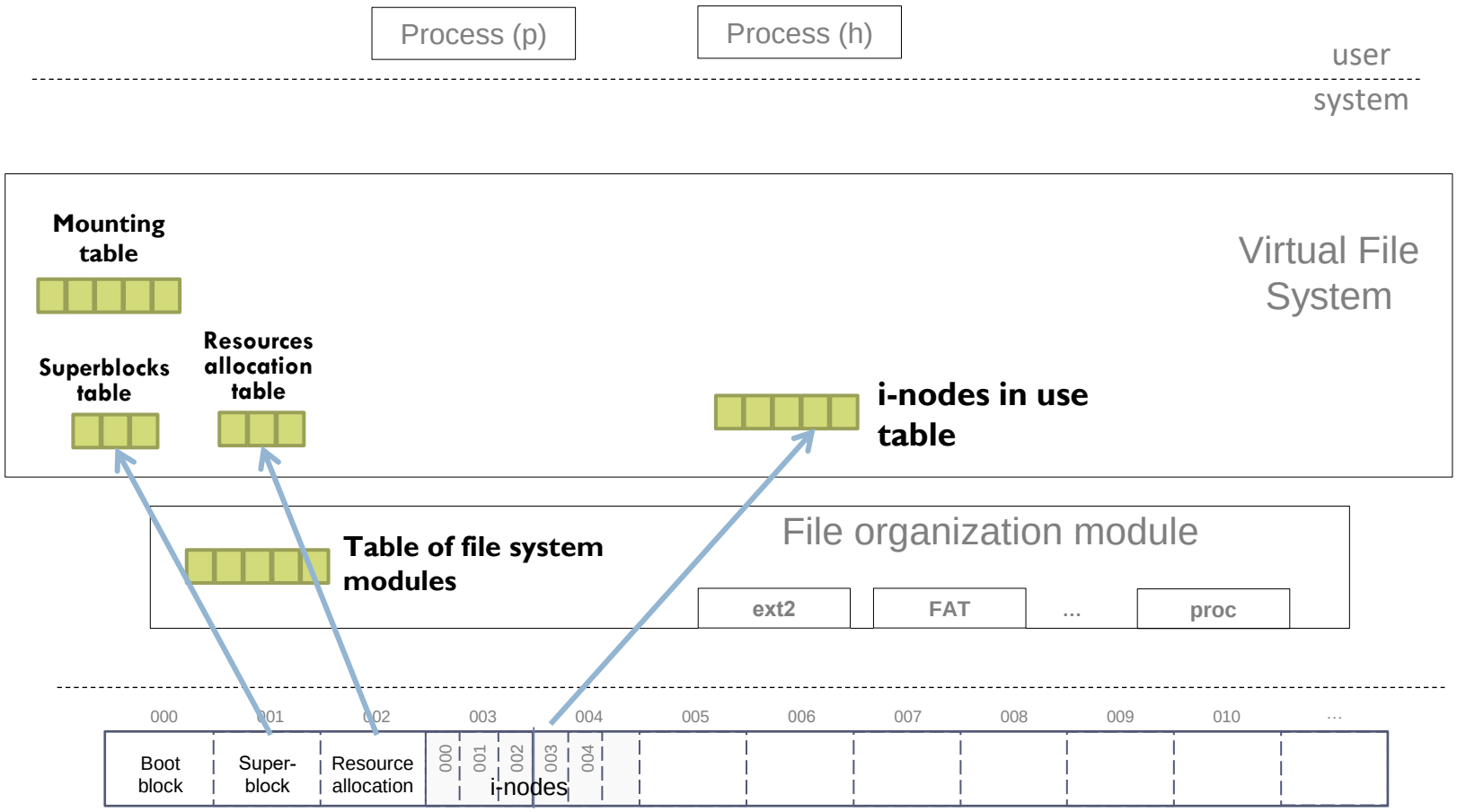


Block/cache management algorithms

getblk	brelse	bread	breada	bwrite

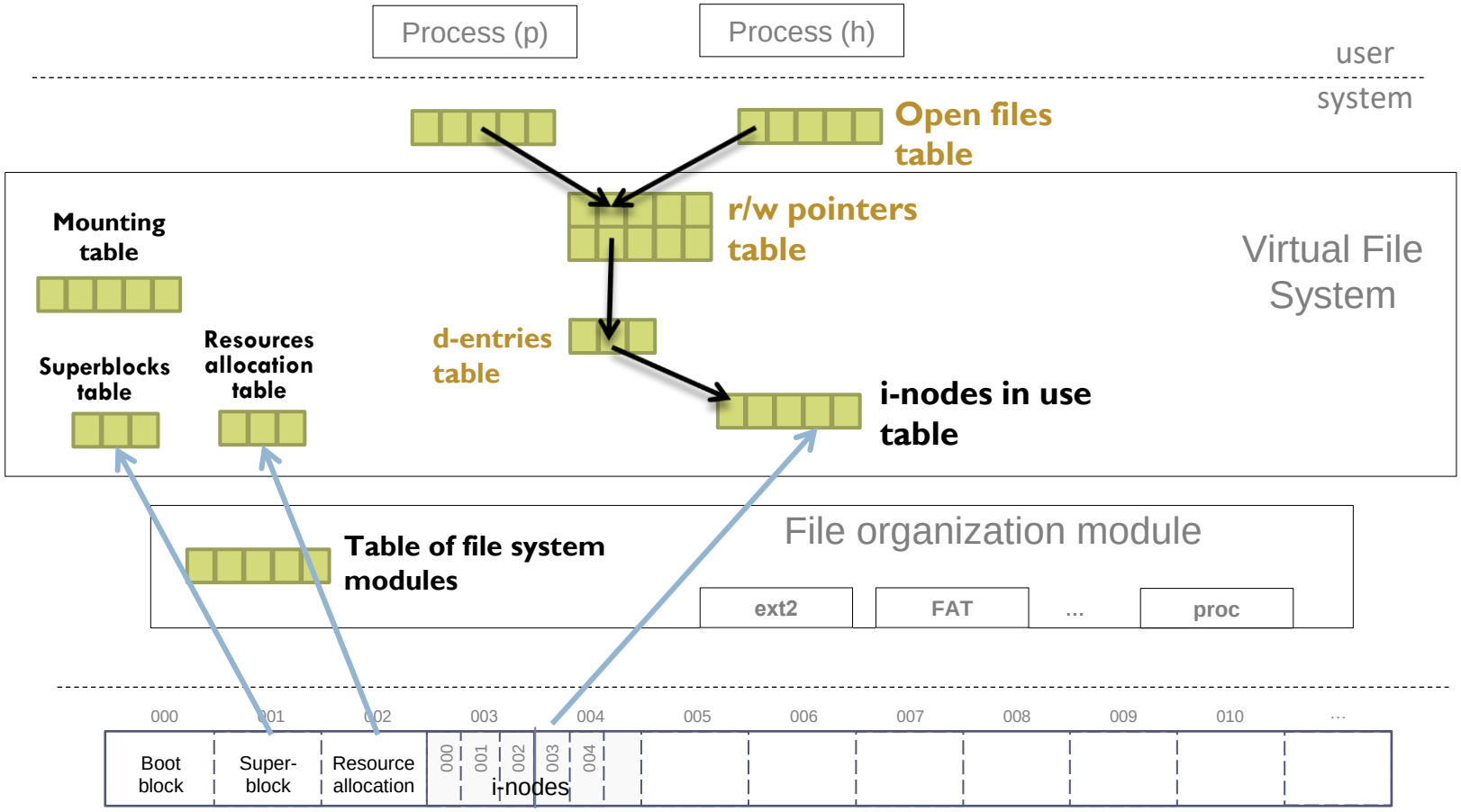
Main management structures
main metadata on disk...

Alejandro Calderón Mateos



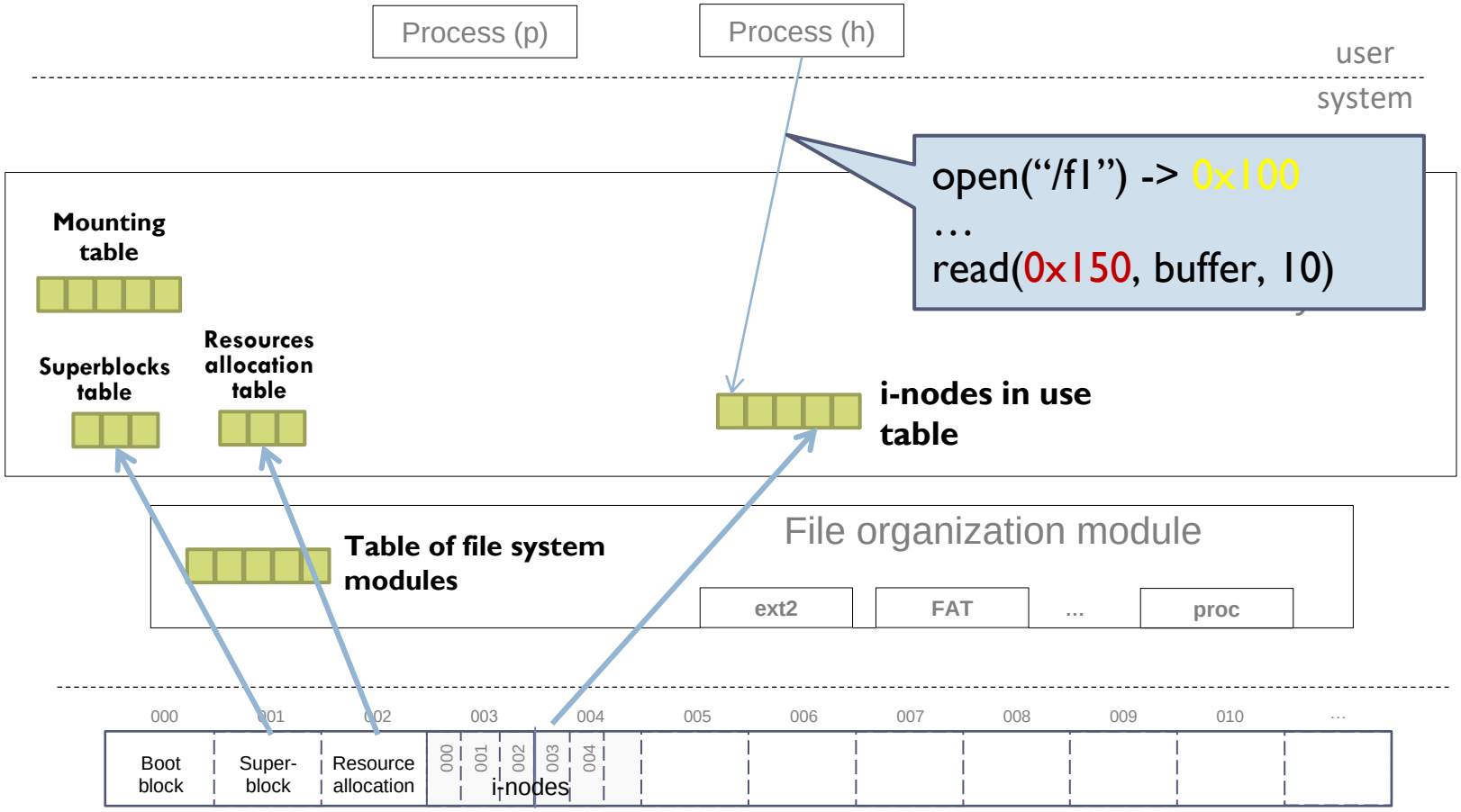
Main management structures
main metadata on disk... + 3

Alejandro Calderón Mateos



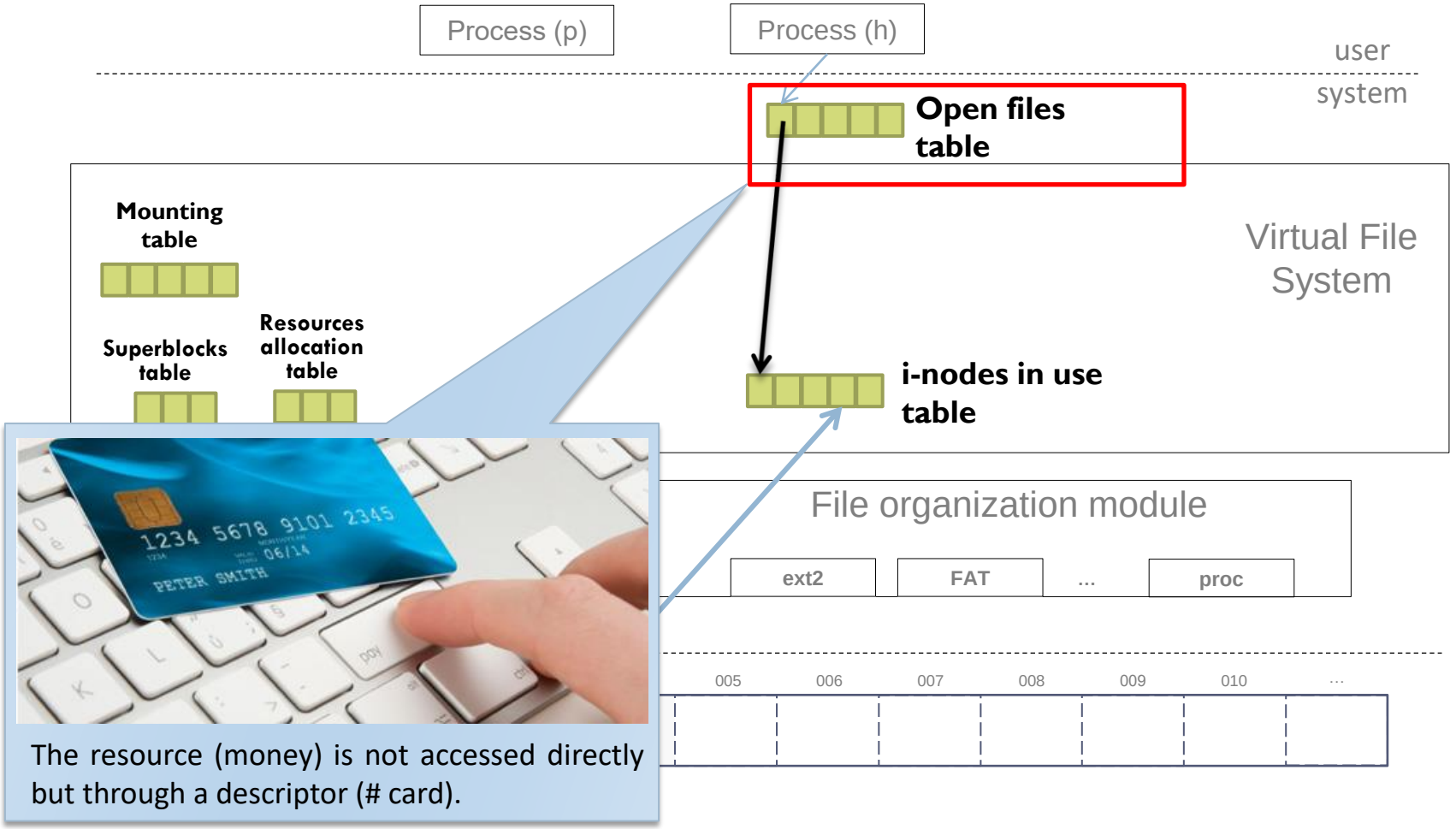
Main management structures
secure API interface?

Alejandro Calderón Mateos



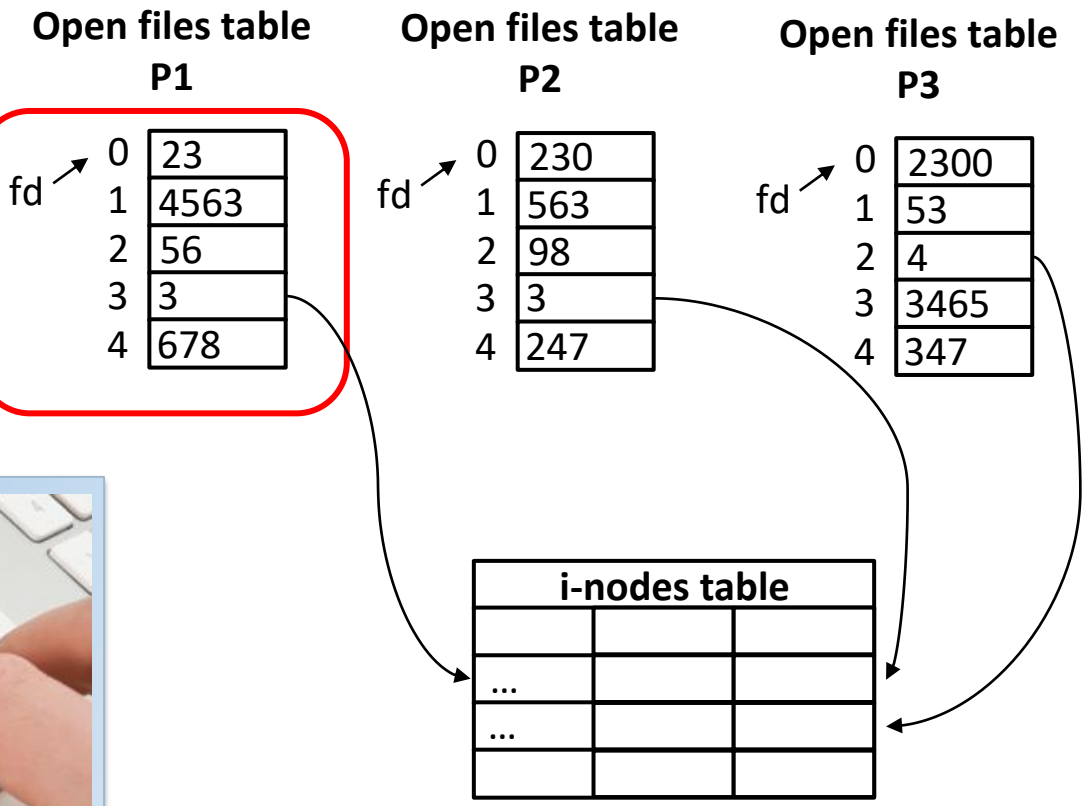
Main management structures
open files table: secure interface

Alejandro Calderón Mateos



Main management structures
open files table: secure interface

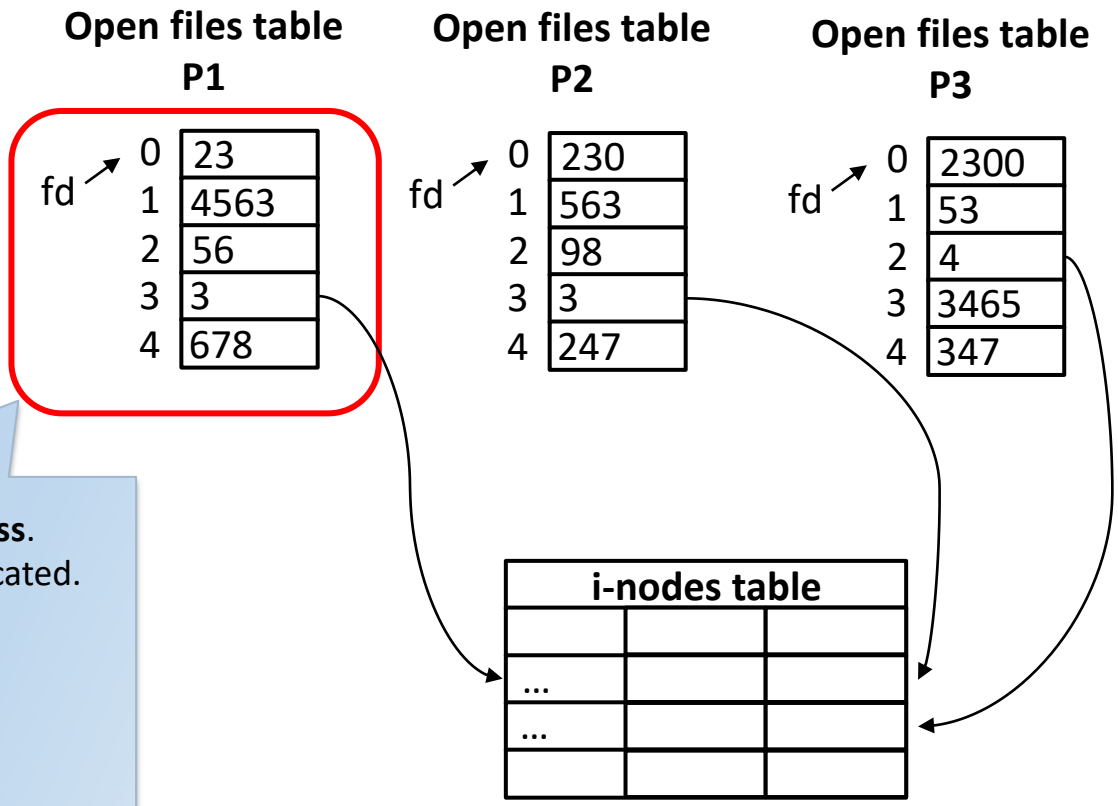
Alejandro Calderón Mateos



The resource (money) is not accessed directly but through a descriptor (# card).

Main management structures
open files table: secure interface

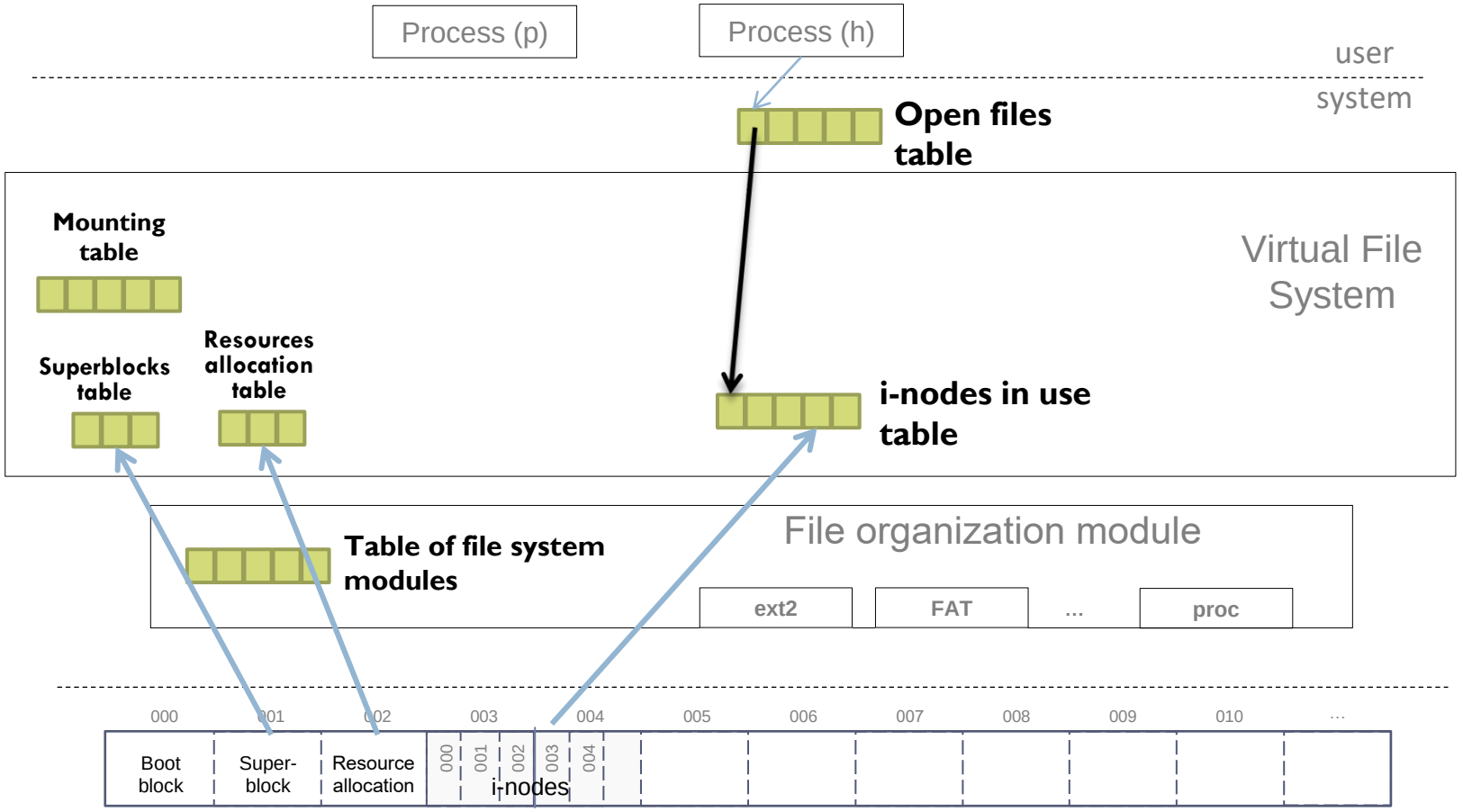
Alejandro Calderón Mateos



- Table **included in the BCP of the process**.
  - When fork() is performed, it is duplicated.
- Table with **one entry per open file**.
  - 0, 1 and 2 used by default.
- **Number of rows limits** the **maximum number of open files per process**.
- The table **is filled in orderly fashion**:
  - open/creat/dup: search first free entry.
  - close: marks entry as free.

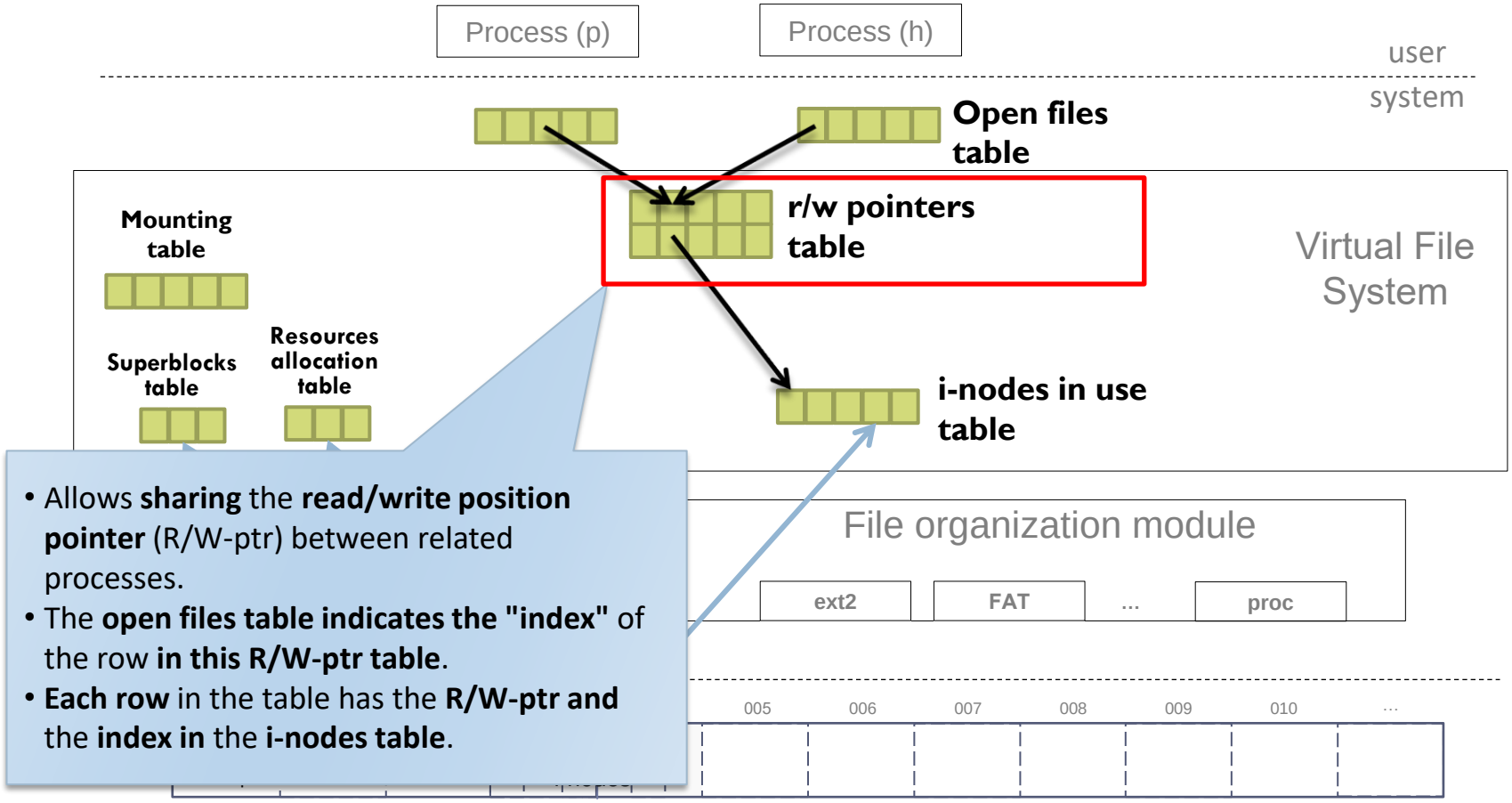
Main management structures
open files table: secure interface

Alejandro Calderón Mateos



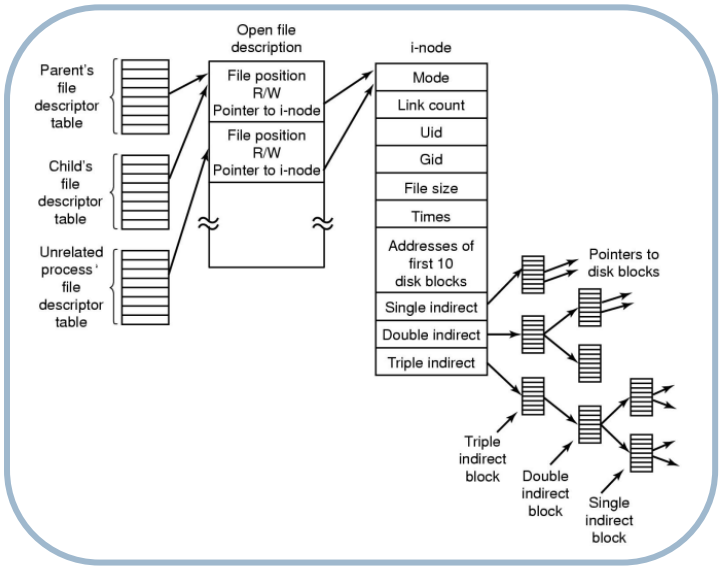
Main management structures
table of file r/w pointers: sharing r/w ptr.

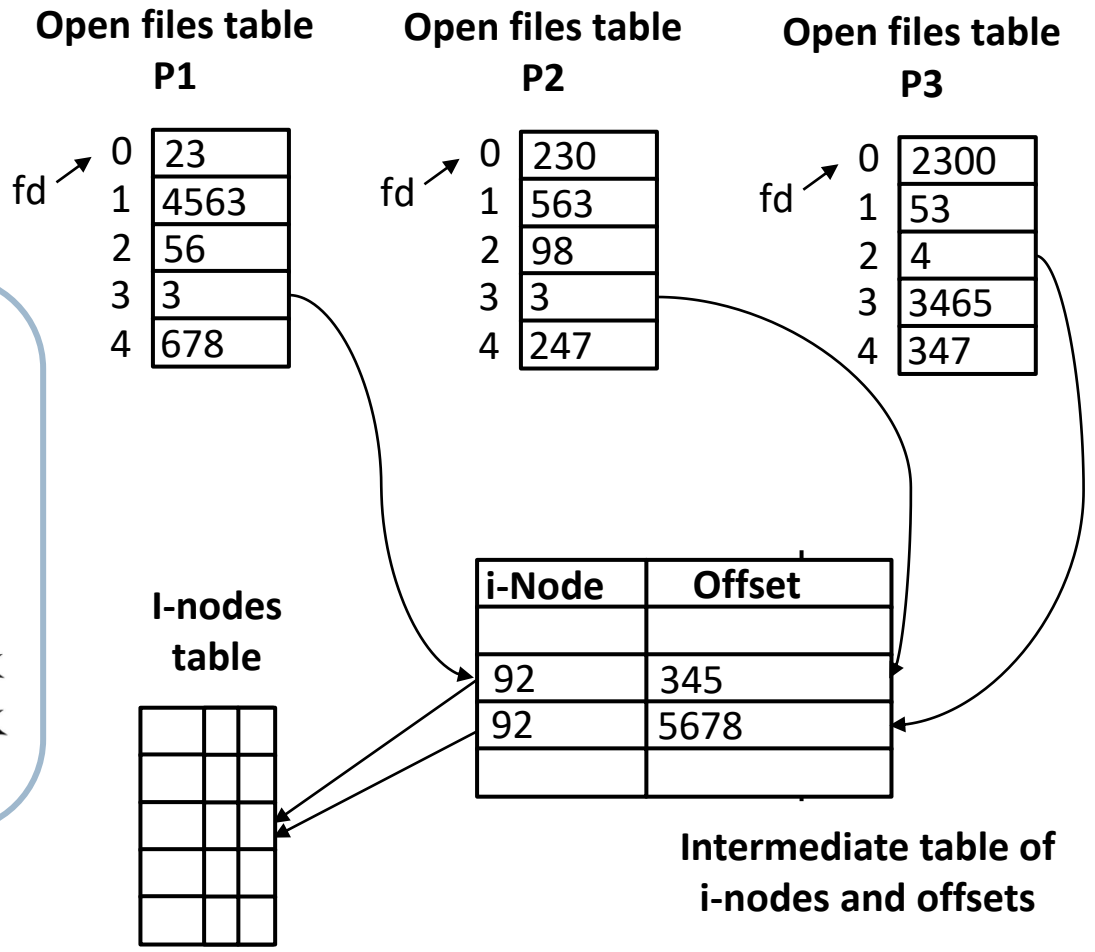
Alejandro Calderón Mateos



- Allows **sharing** the **read/write position pointer** (R/W-ptr) between related processes.
- The **open files table indicates the "index"** of the row **in this R/W-ptr table**.
- **Each row** in the table has the **R/W-ptr and** the **index in** the **i-nodes table**.

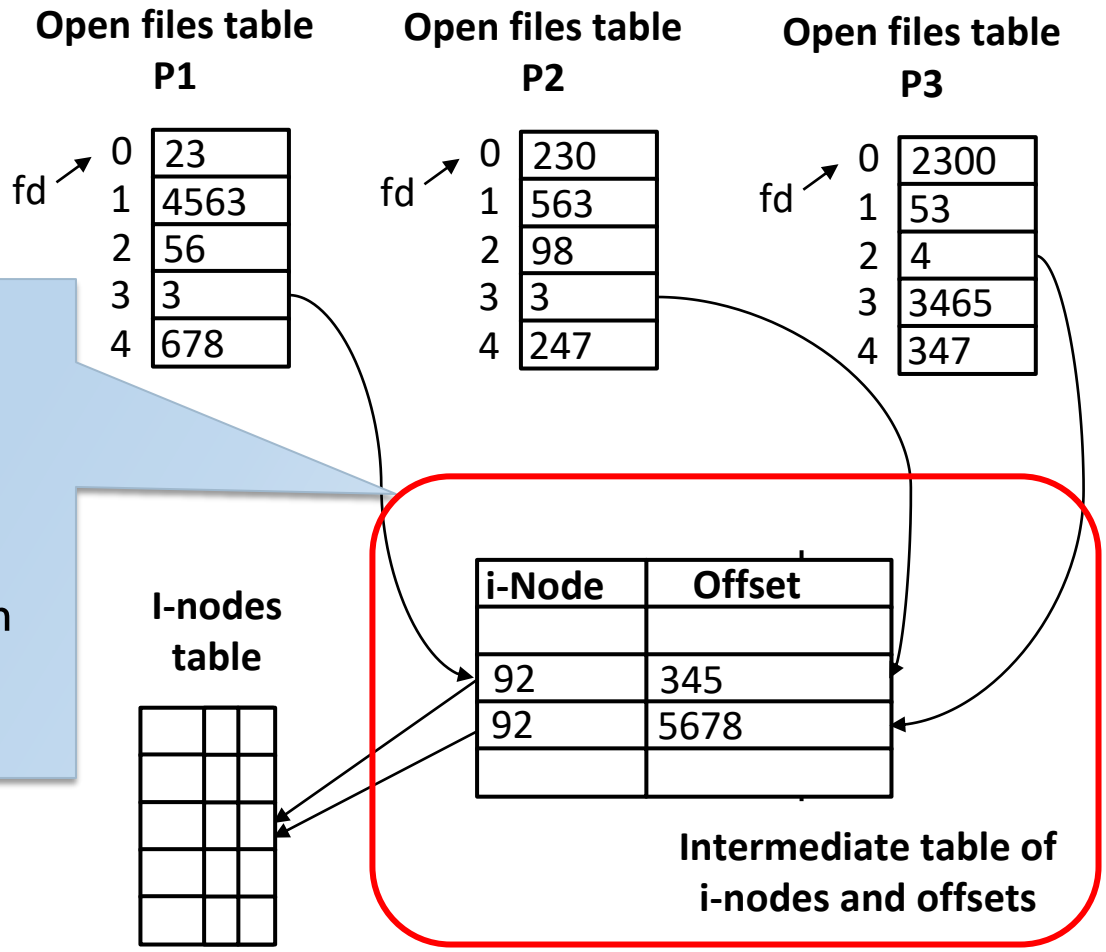
Main management structures
table of file r/w pointers: sharing r/w ptr.





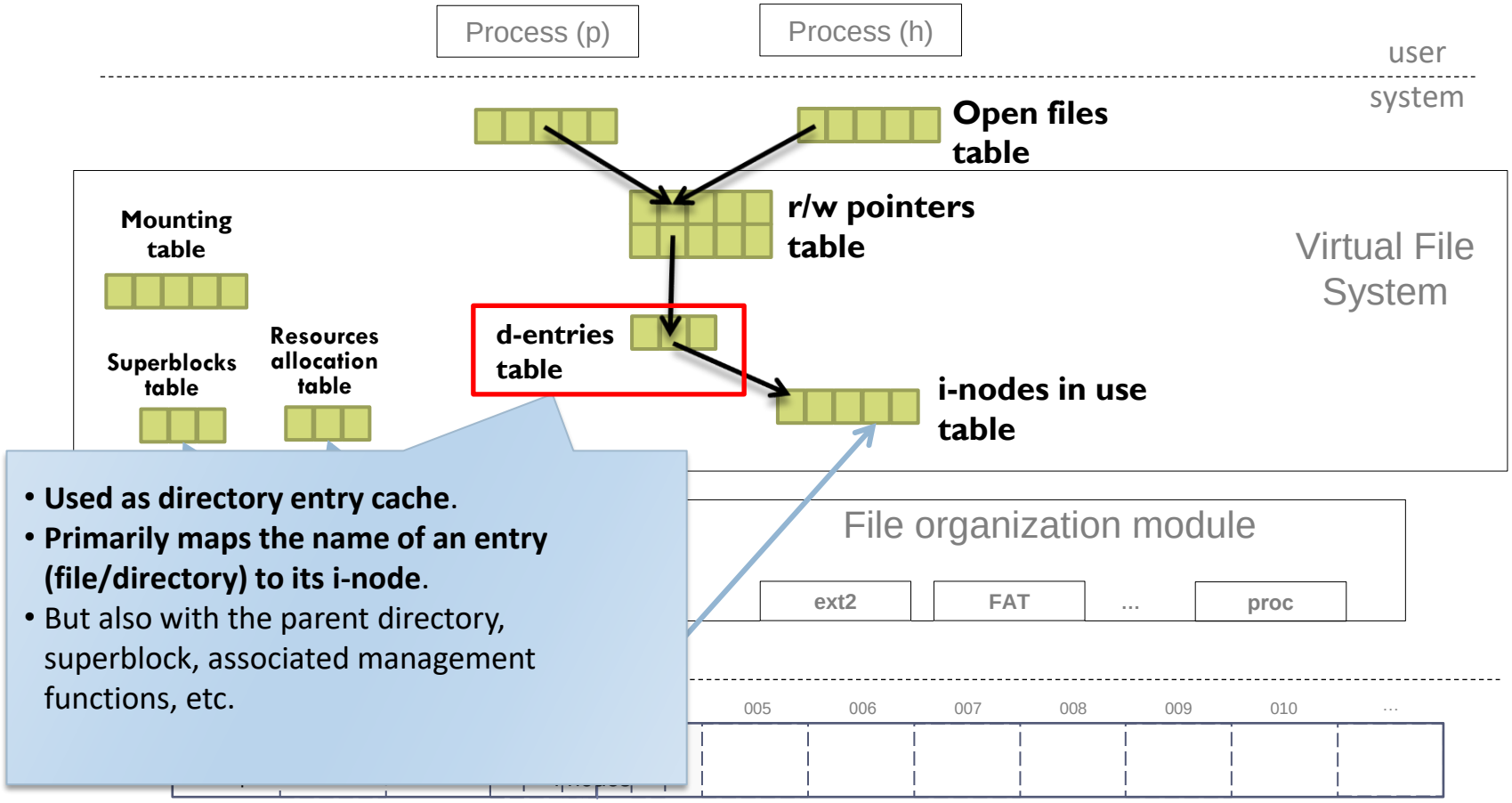
Main management structures
table of file r/w pointers: sharing r/w ptr.

- FILP table (FILe Pointer)
- Between the descriptor table and (usually) the i-node table.
- Saves (mainly) the file position pointer.



Main management structures
d-entries table: working with directories

Alejandro Calderón Mateos

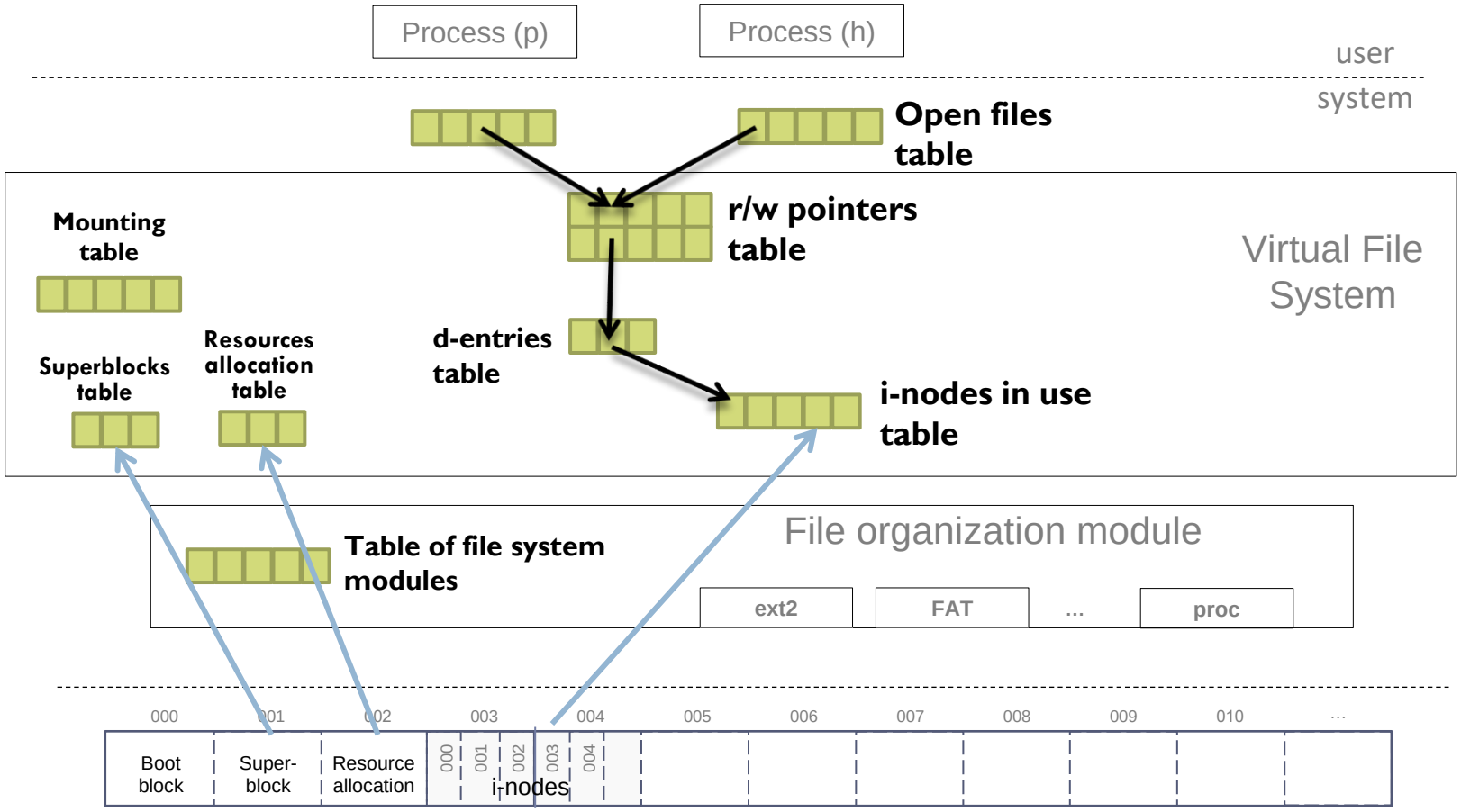


- **Used as directory entry cache**.
- **Primarily maps the name of an entry (file/directory) to its i-node**.
- But also with the parent directory, superblock, associated management functions, etc.

Main management structures

summary of the main data structures in memory

Alejandro Calderón Mateos



Example of memory organization…

https://github.com/acaldero/nanofs

Alejandro Calderón Mateos

```
// Information read from the disk
TypeSuperblock sblocks [1] ;
char imap [numInodo] ;
char bmap [numBlocksData] ;
TypeDiskInode inodos [numInodo] ;

// Extra support information
struct {
    int posicion;
    int abierto;
} inodos_x [numInodo] ;

...
```

(3a) Management of disk/memory structures …

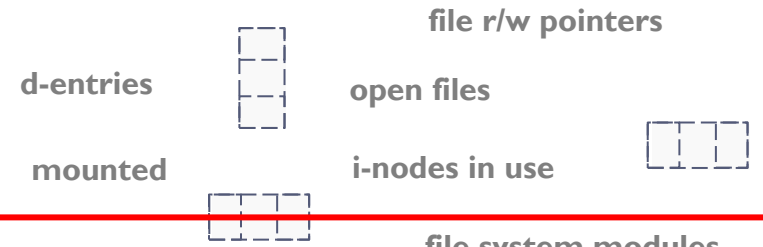
File system calls

Descriptor		Uses namei			i-no. asig.	Attributes	I/O.	File Sys.	View
open	pipe	open	chown	unlink	creat	chown	read	mount	chdir
creat	close	creat	chmod	mknod	mknod	chmod	write	umount	chroot
dup		chdir	stat	mount	link	stat	lseek		
		chroot	link	umount	unlink				

xx

Low-level file system algorithms

namei		ialloc	alloc		bmap
iget	iput	ifree	free		

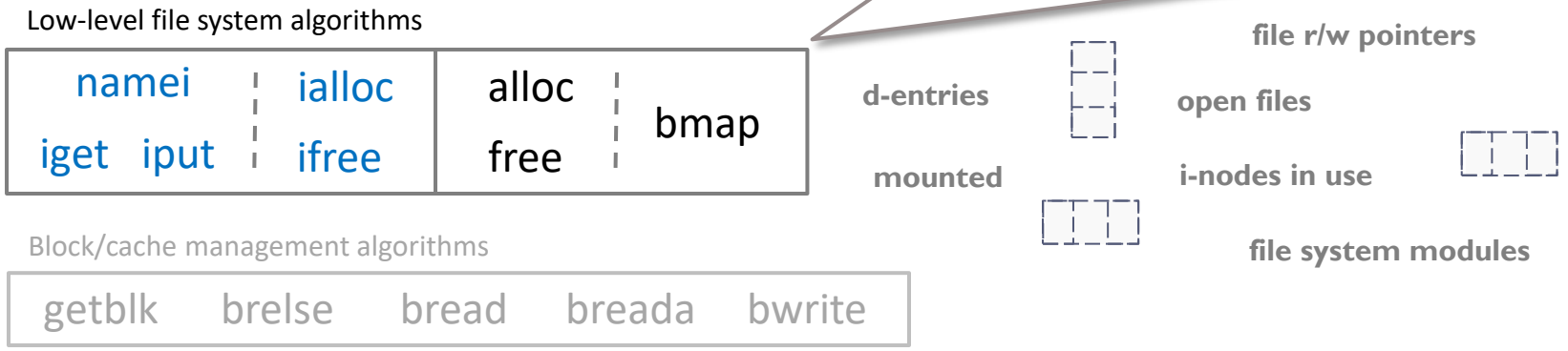


Block/cache management algorithms

getblk	brelse	bread	breada	bwrite

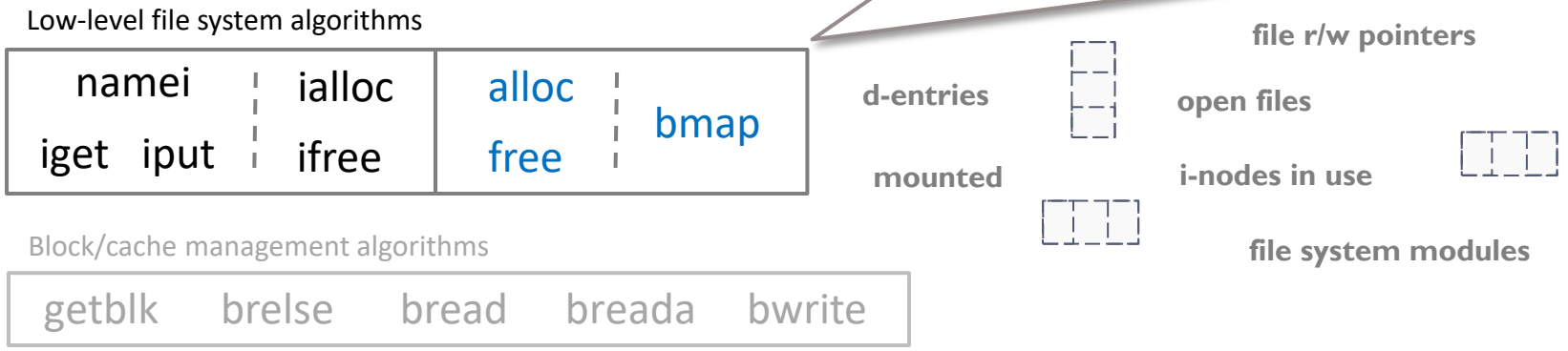
Example of management routines
i-nodes

- **namei**: converts a path to the associated i-node.
- **iget**: returns an i-node from the i-node table and if not present, reads it from secondary memory, adds it to the i-node table and returns it.
- **iput**: releases an i-node from the i-node table, and if necessary, updates it in secondary memory.
- **ialloc**: allocates an i-node to a file.
- **ifree**: releases an i-node previously assigned to a file.



Example of management routines
blocks

- **bmap**: calculates the disk block associated with a file offset.
  Translates logical addresses (file offset) to physical addresses (disk block).
- **alloc**: allocates a block to a file.
- **free**: releases a block previously assigned to a file.



Example: ialloc and alloc

https://github.com/acaldero/nanofs


```
int ialloc ( void )
{
   // buscar un i-nodo libre
   for (int=0; i<sblocks[0].numInodes; i++)
   {
        if (imap[i] == 0) {
           // inodo ocupado ahora
           imap[i] = 1;
           // valores por defecto en el i-nodo
           memset(&(inodos[i]),0,
                  sizeof(TypeDiskInode));
           // devolver identificador de i-nodo
           return i;
        }
   }

   return -1;
}
```

```
int alloc ( void )
{
   char b[BLOCK_SIZE];

   for (int=0; i<sblocks[0].numBlocksData; i++)
   {
        if (bmap[i] == 0) {
           // block ocupado ahora
           bmap[i] = 1;
           // valores por defecto en el block
           memset(b, 0, BLOCK_SIZE);
           bwrite(DISK, sblocks[0].primerBloqueData + i, b);
           // devolver identificador del block
           return i;
        }
   }
   return -1;
}
```

Example: ifree and free

https://github.com/acaldero/nanofs


```
int ifree ( int inodo_id )
{
    // comprobar validez de inodo_id
    if (inodo_id > sblocks[0].numInodes)
        return -1;

    // liberar i-nodo
    imap[inodo_id] = 0;

    return -1;
}
```

```
int free ( int block_id )
{
    // comprobar validez de block_id
    if (block_id > sblocks[0].numBlocksData)
        return -1;

    // liberar block
    bmap[block_id] = 0;

    return -1;
}
```

Example: namei and bmap

https://github.com/acaldero/nanofs


```
int namei ( char *fname )
{
   // buscar i-nodo con nombre <fname>
   for (int=0; i<sblocks[0].numInodes; i++)
   {
        if (! strcmp(inodos[i].nombre, fname))
             return i;
   }

    return -1;
}
```

```
int bmap ( int inodo_id, int offset )
{
    int b[BLOCK_SIZE/4];

    // comprobar validez de inodo_id
    if (inodo_id > sblocks[0].numInodes)
        return -1;

    // block de datos asociado
    if (offset < BLOCK_SIZE)
        return inodos[inodo_id].blockDirecto;
    if (offset < BLOCK_SIZE*BLOCK_SIZE/4) {
        bread(DISK, sblocks[0].primerBloqueData +
                    inodos[inodo_id].blockIndirecto, b);
        offset = (offset – BLOCK_SIZE) / BLOCK_SIZE;
        return b[offset] ;
    }

    return -1;
}
```

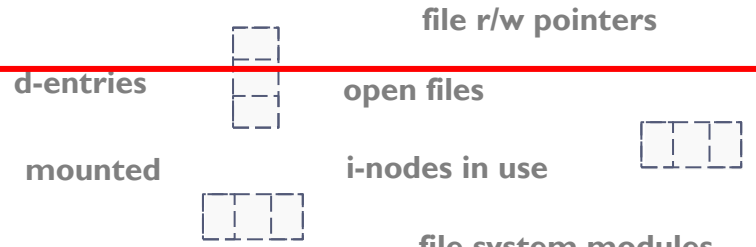
(3b) System calls…

File system calls

Descriptor	Uses namei	i-no. asig.	Attributes	I/O.	File Sys.	View
open pipe creat close dup	open chown unlink creat chmod mknod chdir stat mount chroot link umount	creat mknod link unlink	chown chmod stat	read write lseek	mount umount	chdir chroot

Low-level file system algorithms

namei	ialloc	alloc	
iget iput	ifree	free	bmap



Block/cache management algorithms

getblk	brelse	bread	breada	bwrite

Example
sys. calls

- **open**: locates the i-node associated with the path of the file, …
- **read**: locates the data block, read data block, …
- **write**: locate the data block, write data block, …
- …

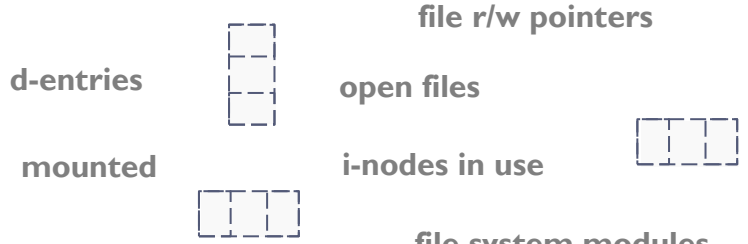
ejandro Calderón Mateos

File system calls

Descriptor	Uses namei	i-no. asig.	Attributes	I/O.	File Sys.	View
open pipe creat close dup	open chown unlink creat chmod mknod chdir stat mount chroot link umount	creat mknod link unlink	chown chmod stat	read write lseek	mount umount	chdir chroot

Low-level file system algorithms

namei	ialloc	alloc	bmap
iget iput	ifree	free	



Block/cache management algorithms

getblk brelse bread breada bwrite

Example: mount

https://github.com/acaldero/nanofs


```
int mount ( void )
{
   // leer block 0 de disco en sblocks[0]
   bread(DISK, 1, &(sblocks[0]) );

   // leer los blocks para el mapa de i-nodes
   for (int=0; i<sblocks[0].numBlocksInodeMap; i++)
        bread(DISK, 2+i, ((char *)imap + i*BLOCK_SIZE) ;

   // leer los blocks para el mapa de blocks de datos
   for (int=0; i<sblocks[0].numBlocksDataMap; i++)
       bread(DISK, 2+i+sblocks[0].numBlocksInodeMap, ((char *)bmap + i*BLOCK_SIZE);

   // leer los i-nodes a memoria
   for (int=0; i<(sblocks[0].numInodes*sizeof(TypeDiskInode)/BLOCK_SIZE); i++)
       bread(DISK, i+sblocks[0].firstInode, ((char *)inodos + i*BLOCK_SIZE);

   return 1;
}
```

Example: umount

https://github.com/acaldero/nanofs


```
int umount ( void )
{
    // escribir block 0 de sblocks[0] a disco
    bwrite(DISK, 1, &(sblocks[0]) );

    // escribir los blocks para el mapa de i-nodes
    for (int=0; i<sblocks[0].numBlocksInodeMap; i++)
         bwrite(DISK, 2+i, ((char *)imap + i*BLOCK_SIZE) ;

    // escribir los blocks para el mapa de blocks de datos
    for (int=0; i<sblocks[0].numBlocksDataMap; i++)
        bwrite(DISK, 2+i+sblocks[0].numBlocksInodeMap, ((char *)bmap + i*BLOCK_SIZE);

    // escribir los i-nodes a disco
    for (int=0; i<(sblocks[0].numInodes*sizeof(TypeDiskInode)/BLOCK_SIZE); i++)
        bwrite(DISK, i+sblocks[0].firstInode, ((char *)inodos + i*BLOCK_SIZE);

    return 1;
}
```

Example: mkfs

https://github.com/acaldero/nanofs


```
int mkfs ( void )
{
    // inicializar a los valores por defecto del superblock, mapas e i-nodes
    sblocks[0].numMagico = 1234; // ayuda a comprobar que se haya creado por nuestro mkfs
    sblocks[0].numInodes = numInodo;
    …
    for (int=0; i<sblocks[0].numInodes; i++)
          imap[i] = 0; // free
    for (int=0; i<sblocks[0].numBlocksData; i++)
          bmap[i] = 0; // free
    for (int=0; i<sblocks[0].numInodes; i++)
         memset(&(inodos[i]), 0, sizeof(TypeDiskInode) );

    // to write the default file system into disk
    umount();

    return 1;
}
```

Example: open and close

https://github.com/acaldero/nanofs


```
int open ( char *nombre )
{
    int inodo_id ;

    inodo_id = namei(nombre) ;
    if (inodo_id < 0)
        return inodo_id ;

    inodos_x[inodo_id].posicion = 0;
    inodos_x[inodo_id].abierto   = 1;

    return inodo_id;
}
```

```
int close ( int fd )
{



    if (fd < 0)
        return fd ;

    inodos_x[fd].posicion = 0;
    inodos_x[fd].abierto   = 0;

    return 1;
}
```

Example: creat and unlink

https://github.com/acaldero/nanofs


```
int creat ( char *nombre )
{
    int b_id, inodo_id ;

    inodo_id = ialloc() ;
    if (inodo_id < 0) { return inodo_id ; }
    b_id = alloc();
    if (b_id < 0) { ifree(inodo_id); return b_id ; }

    inodos[inodo_id].type = 1 ; // FICHERO
    strcpy(inodos[inodo_id].nombre, nombre);
    inodos[inodo_id].blockDirecto = b_id ;
    inodos_x[inodo_id].posicion = 0;
    inodos_x[inodo_id].abierto   = 1;

    return 1;
}
```

```
int unlink ( char * nombre )
{
    int inodo_id ;

    inodo_id = namei(nombre) ;
    if (inodo_id < 0)
        return inodo_id ;

    free(inodos[inodo_id].blockDirecto);
    memset(&(inodos[inodo_id]),
                0,
                sizeof(TypeDiskInode));
    ifree(inodo_id) ;

   return 1;
}
```

Example: read and write

https://github.com/acaldero/nanofs


```
int read ( int fd, char *buffer, int size )
{
   char b[BLOCK_SIZE] ;
   int b_id ;

   if (inodos_x[fd].posicion+size > inodos[fd].size)
      size = inodos[fd].size - inodos_x[fd].posicion;
   if (size =< 0)
      return 0;

   b_id = bmap(fd, inodos_x[fd].posicion);
   bread(DISK,
         sblocks[0].primerBloqueData+b_id, b);
   memmove(buffer,
               b+inodos_x[fd].posicion, size);
   inodos_x[fd].posicion += size;

   return size;
}
```

```
int write ( int fd, char *buffer, int size )
{
   char b[BLOCK_SIZE] ;
   int b_id ;

   if (inodos_x[fd].posicion+size > BLOCK_SIZE)
      size = BLOCK_SIZE - inodos_x[fd].posicion;
   if (size =< 0)
      return 0;

   b_id = bmap(fd, inodos_x[fd].posicion);
   bread(DISK, sblocks[0].primerBloqueData+b_id, b);
   memmove(b+inodos_x[fd].posicion,
               buffer, size);
   bwrite(DISK, sblocks[0].primerBloqueData+b_id, b);
   inodos_x[fd].posicion += size;

   return size;
}
```

OPERATING SYSTEMS: FILE SYSTEMS

Files, directories and file systems