Linux For Embedded Systems

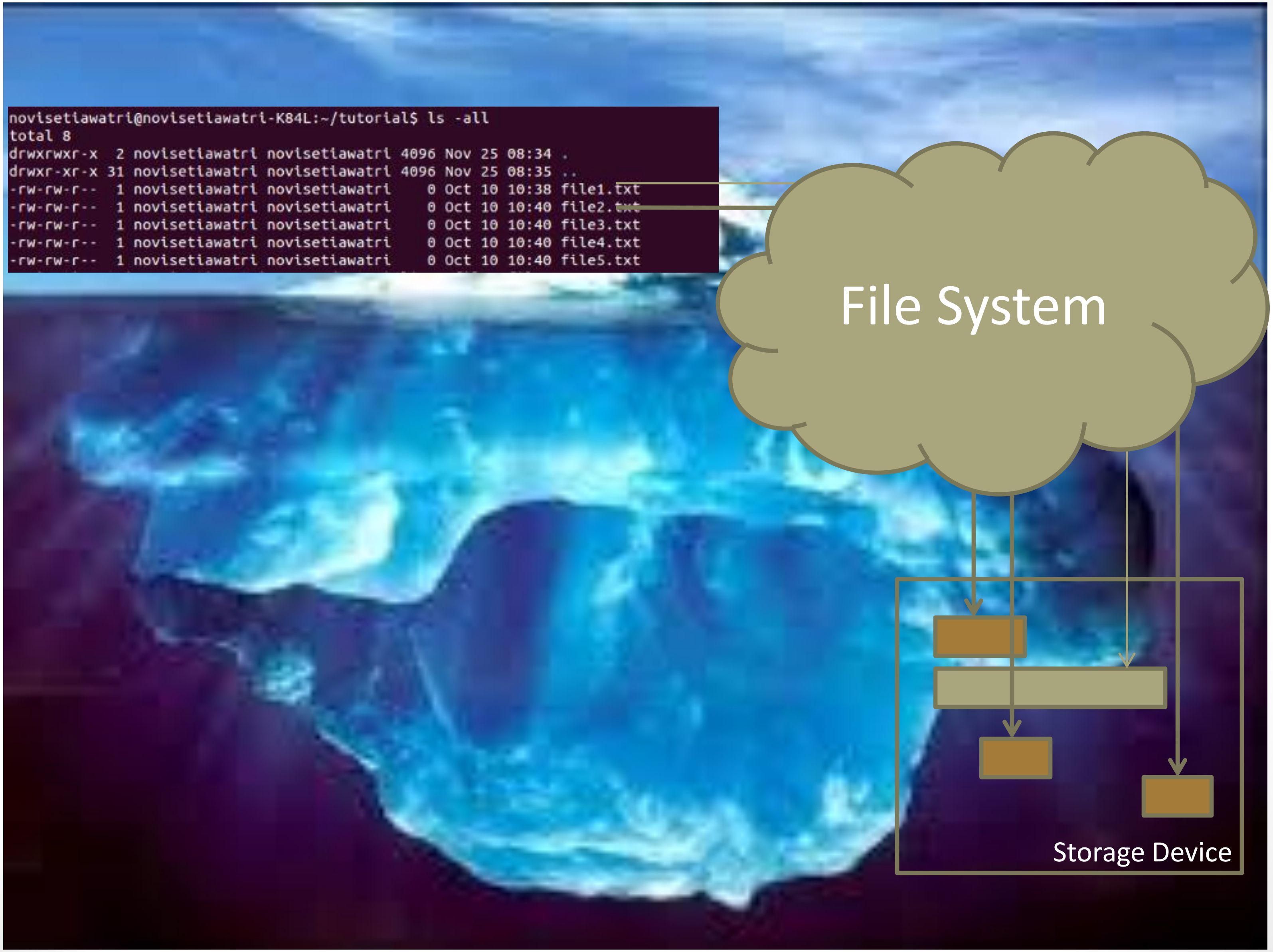
*For Arabs*

# Course 102:

## Understanding Linux

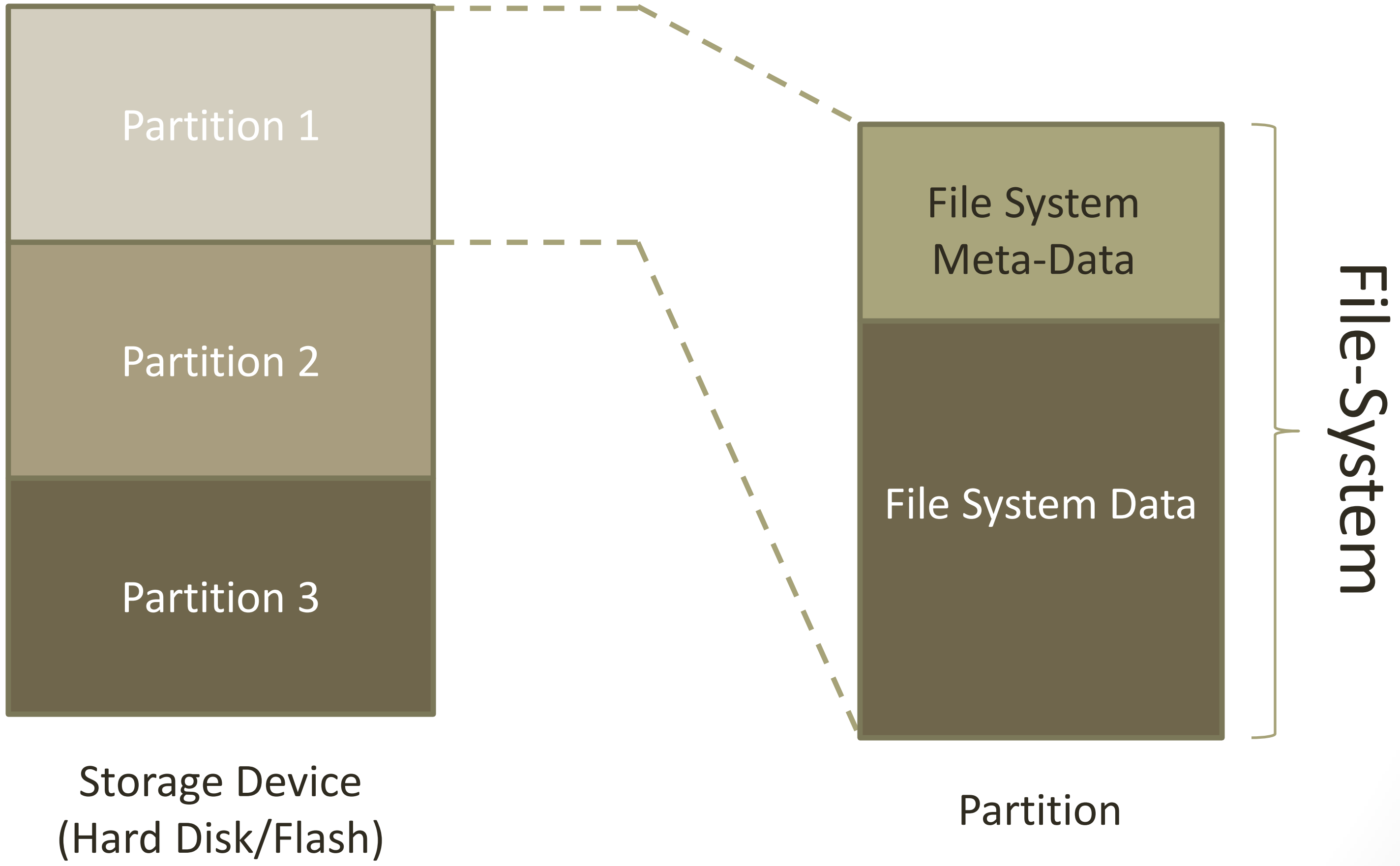
Ahmed ElArabawy

# Lecture 5:
# File Handling Internals



```
novisetiawatri@novisetiawatri-K84L:~/tutorial$ ls -all
total 8
drwxrwxr-x  2 novisetiawatri novisetiawatri 4096 Nov 25 08:34 .
drwxr-xr-x 31 novisetiawatri novisetiawatri 4096 Nov 25 08:35 ..
-rw-rw-r--  1 novisetiawatri novisetiawatri    0 Oct 10 10:38 file1.txt
-rw-rw-r--  1 novisetiawatri novisetiawatri    0 Oct 10 10:40 file2.txt
-rw-rw-r--  1 novisetiawatri novisetiawatri    0 Oct 10 10:40 file3.txt
-rw-rw-r--  1 novisetiawatri novisetiawatri    0 Oct 10 10:40 file4.txt
-rw-rw-r--  1 novisetiawatri novisetiawatri    0 Oct 10 10:40 file5.txt
```

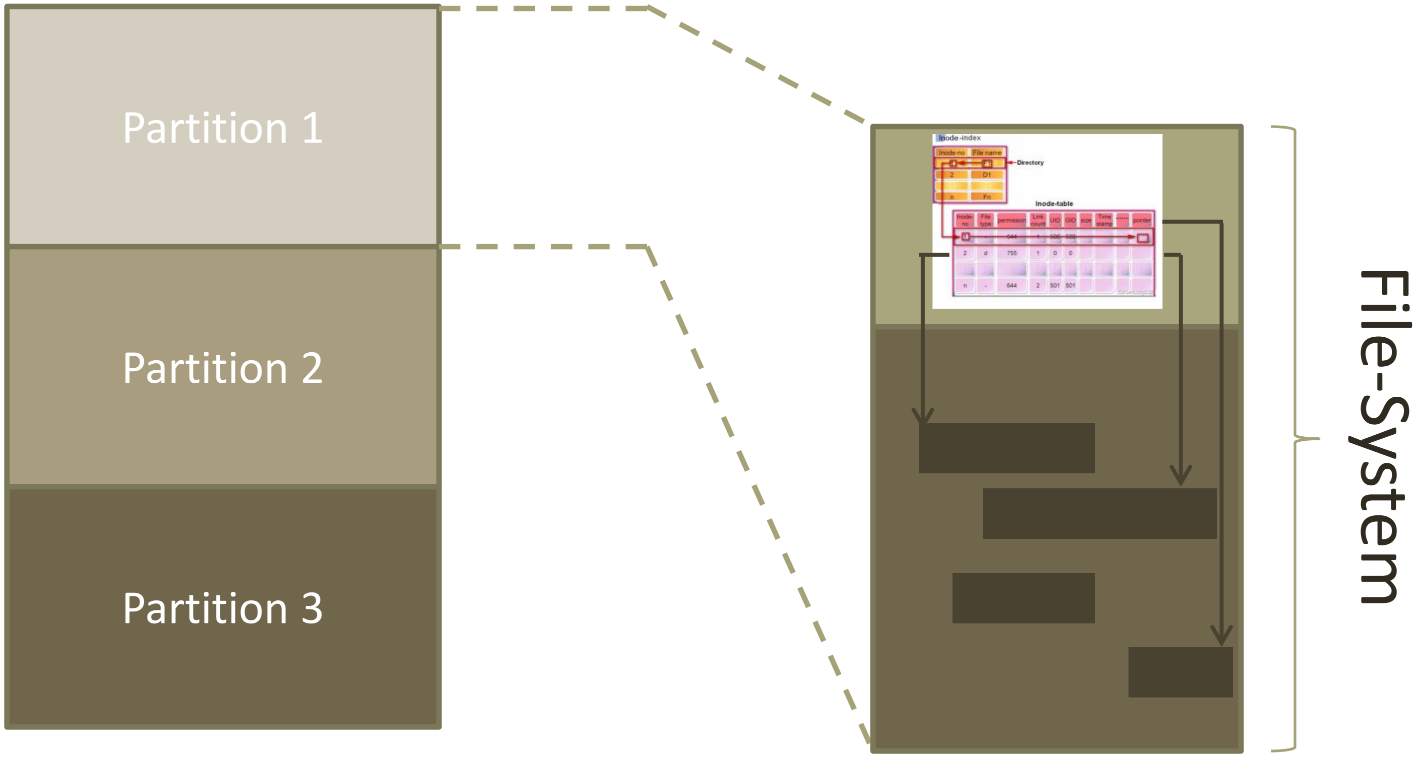
# FileSystem



Storage Device
(Hard Disk/Flash)

Partition

# File-System



Inode-index

| Inode-no | File name |
|---|---|
| 1 | F1 |
| 2 | D1 |
| : | : |
| n | Fn |

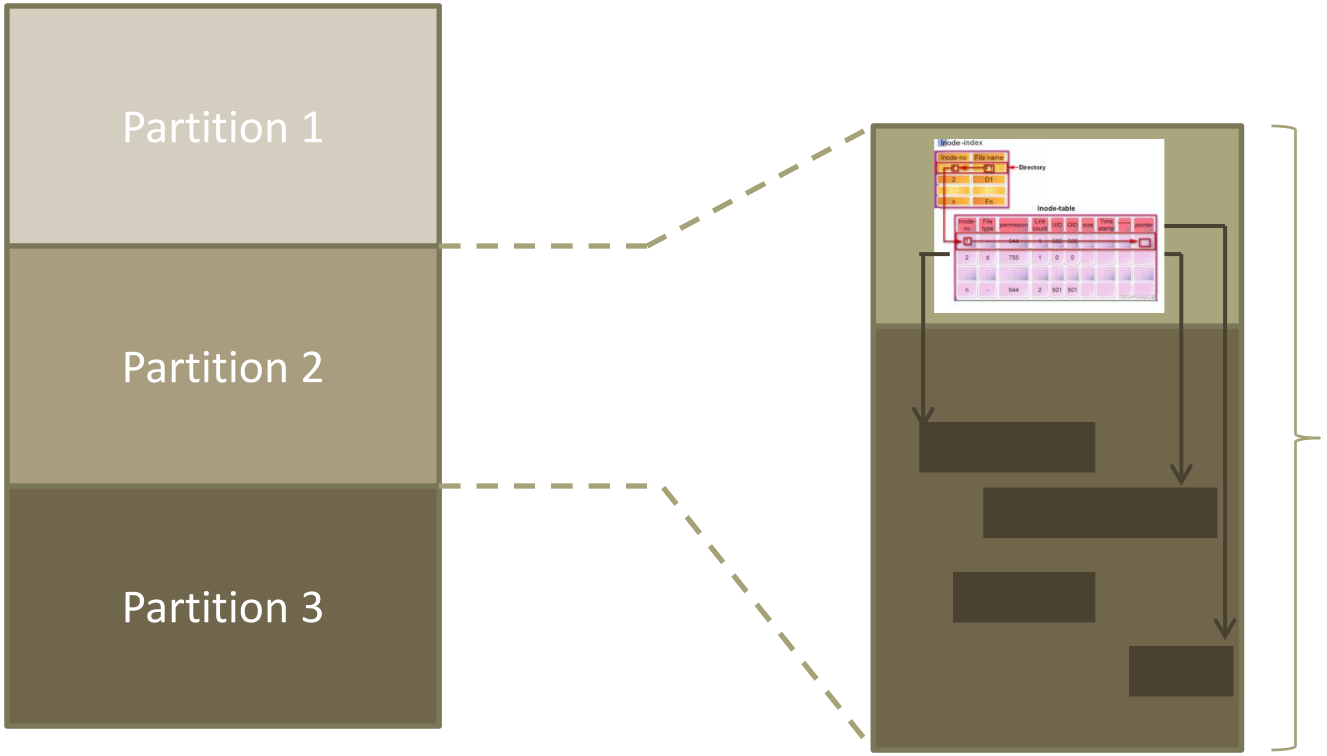
Inode-table

| Inode-no | File type | permission | Link count | UID | GID | size | Time stamp | ....... | pointer |
|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 644 | 1 | 500 | 500 | | | | |
| 2 | d | 755 | 1 | 0 | 0 | | | | |
| : | : | : | : | : | : | : | : | : | : |
| n | - | 644 | 2 | 501 | 501 | | | | |

Storage Device
(Hard Disk/Flash)

Partition

# File-System



Inode-index

| Inode-no | File name |
|---|---|
| 1 | F1 |
| 2 | D1 |
| ⋮ | ⋮ |
| n | Fn |

Directory

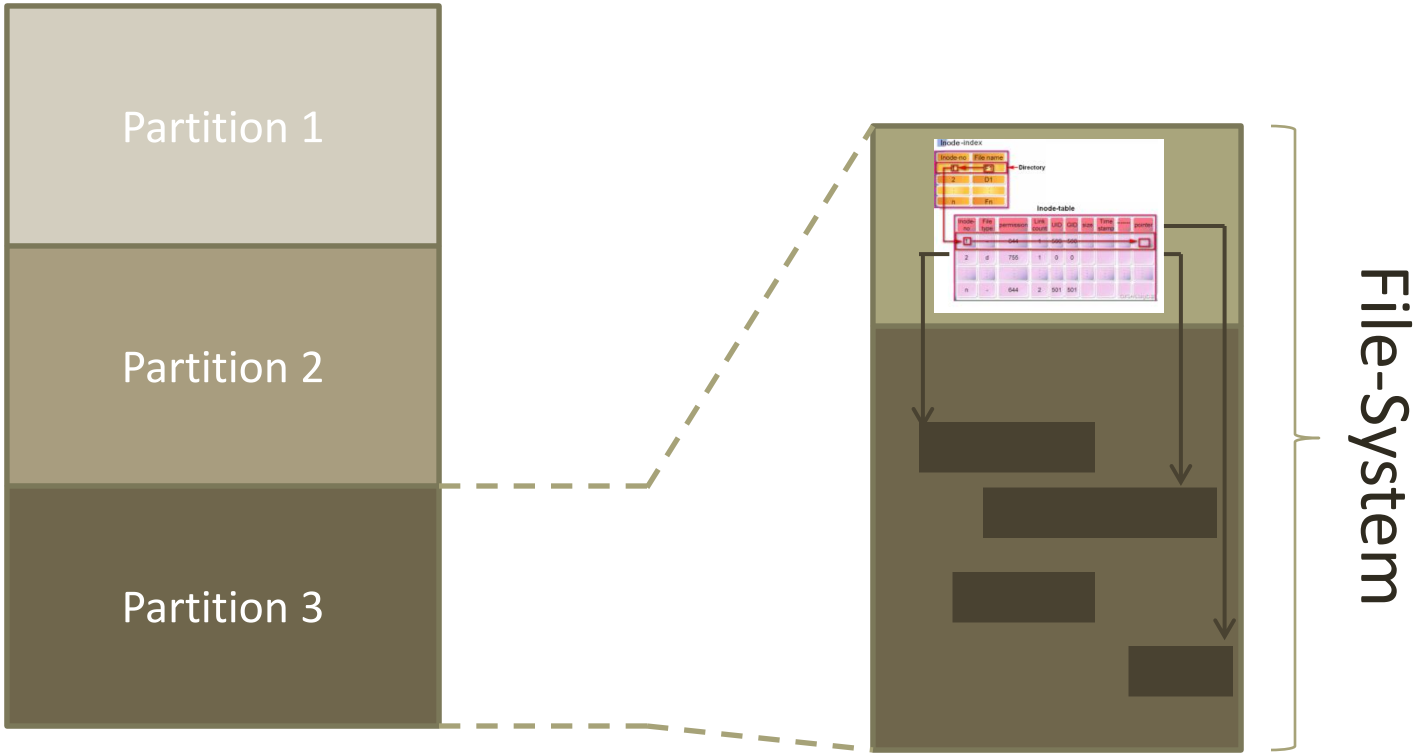
Inode-table

| Inode-no | File type | permission | Link count | UID | GID | size | Time stamp | ------- | pointer |
|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 644 | 1 | 500 | 500 | | | | |
| 2 | d | 755 | 1 | 0 | 0 | | | | |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| n | - | 644 | 2 | 501 | 501 | | | | |

Storage Device
(Hard Disk/Flash)

Partition

# File-System



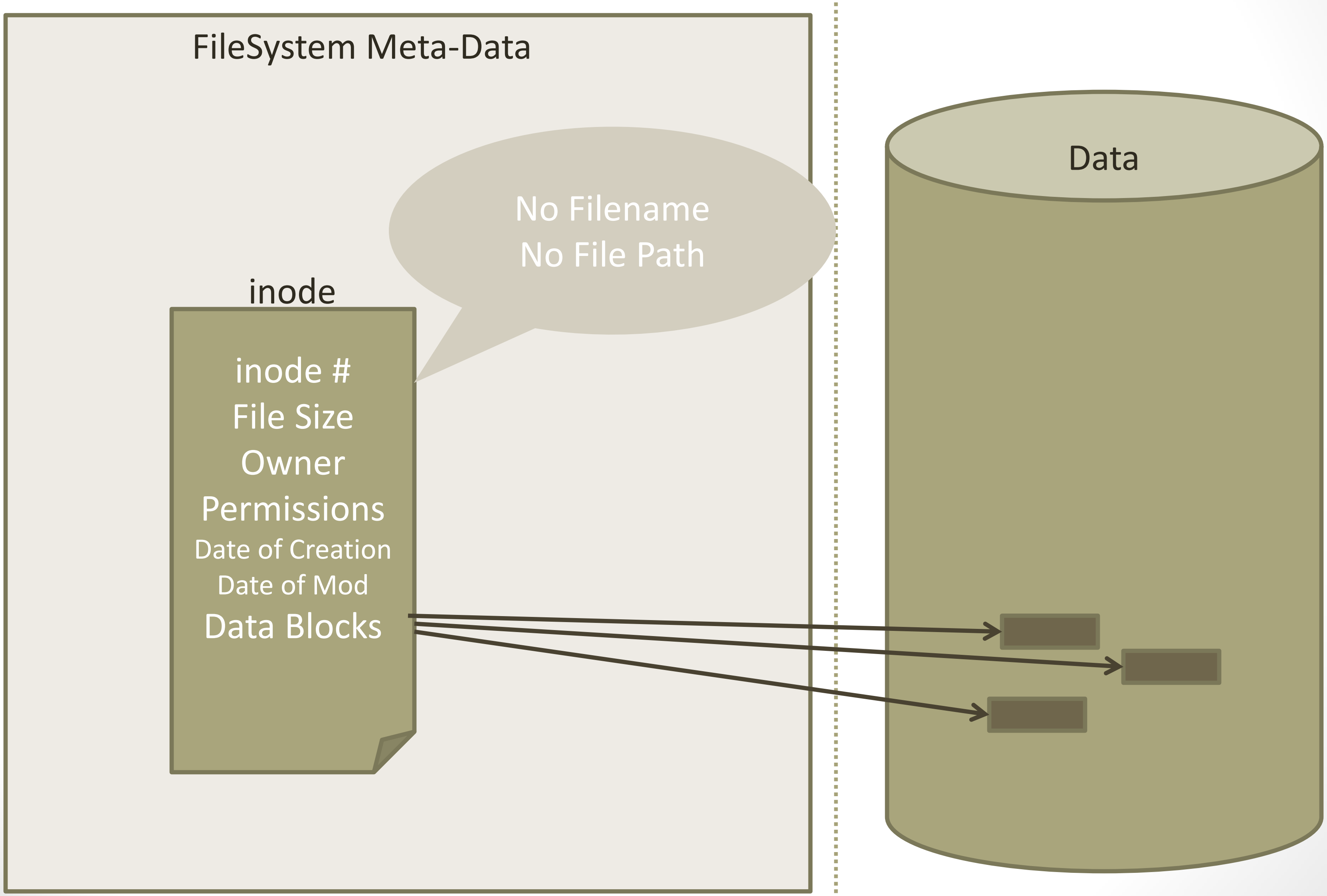
| Inode-no | File name |
|---|---|
| 1 | F1 |
| 2 | D1 |
| ⋮ | ⋮ |
| n | Fn |

| Inode-no | File type | permission | Link count | UID | GID | size | Time stamp | ...... | pointer |
|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 644 | 1 | 500 | 500 | | | | |
| 2 | d | 755 | 1 | 0 | 0 | | | | |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| n | - | 644 | 2 | 501 | 501 | | | | |

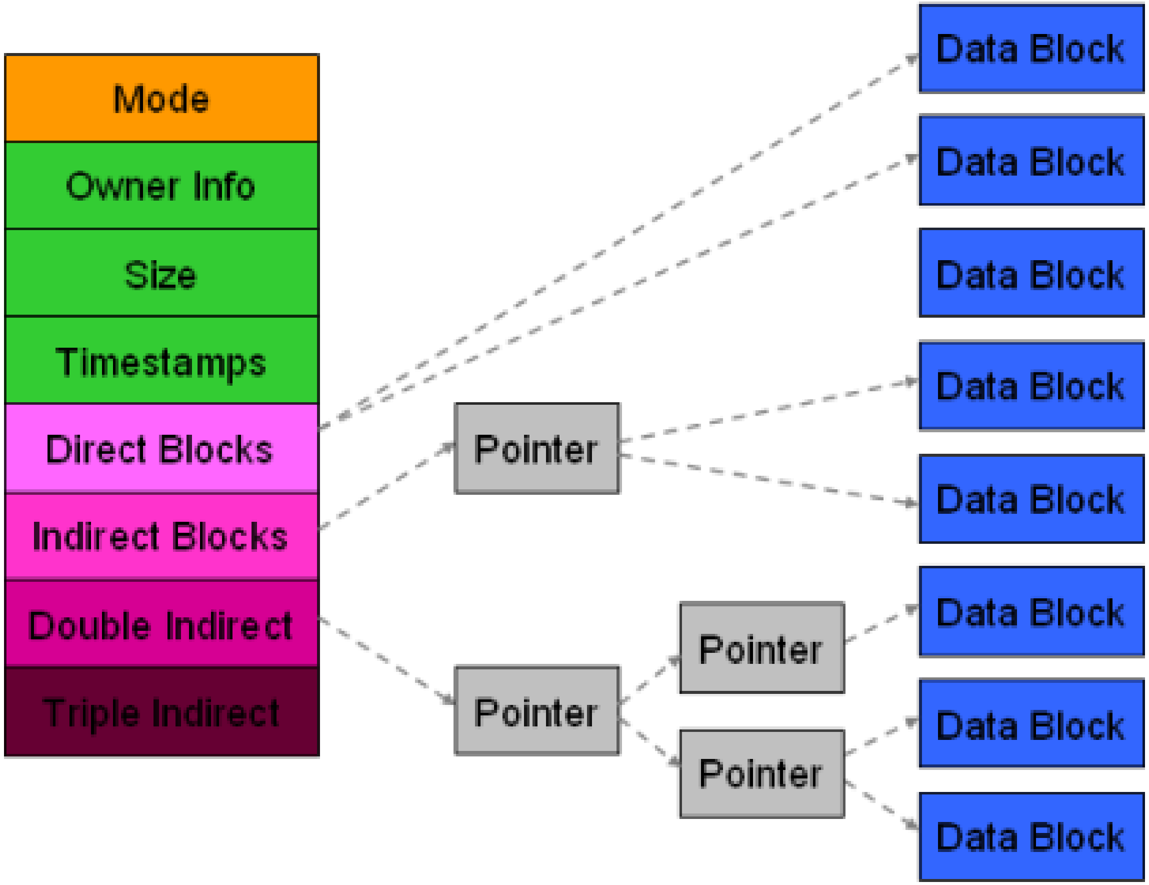
Storage Device
(Hard Disk/Flash)

Partition

# What is a File ???



# The “inode” Structure



# What is a File ??

- A file is a set of bytes that represent some content (pdf document, excel sheet, binary executable, … )
- The file is stored in a (partition in a) storage device as a single data block or fragmented into a group of data blocks (within the same partition)
- The fileSystem is responsible for managing the data block(s), and their representation to the user
- For this management, the fileSystem needs to maintain some extra info about the file which is called file Meta-data
  - File Size
  - File Owner (user & group)
  - File Permissions
  - Data of creation/last modification
  - Pointers to the file content data blocks
  - etc …
- These meta-data are stored in an “inode” structure
- Note: the inode does not contain the file name or its location

# What is a File ??

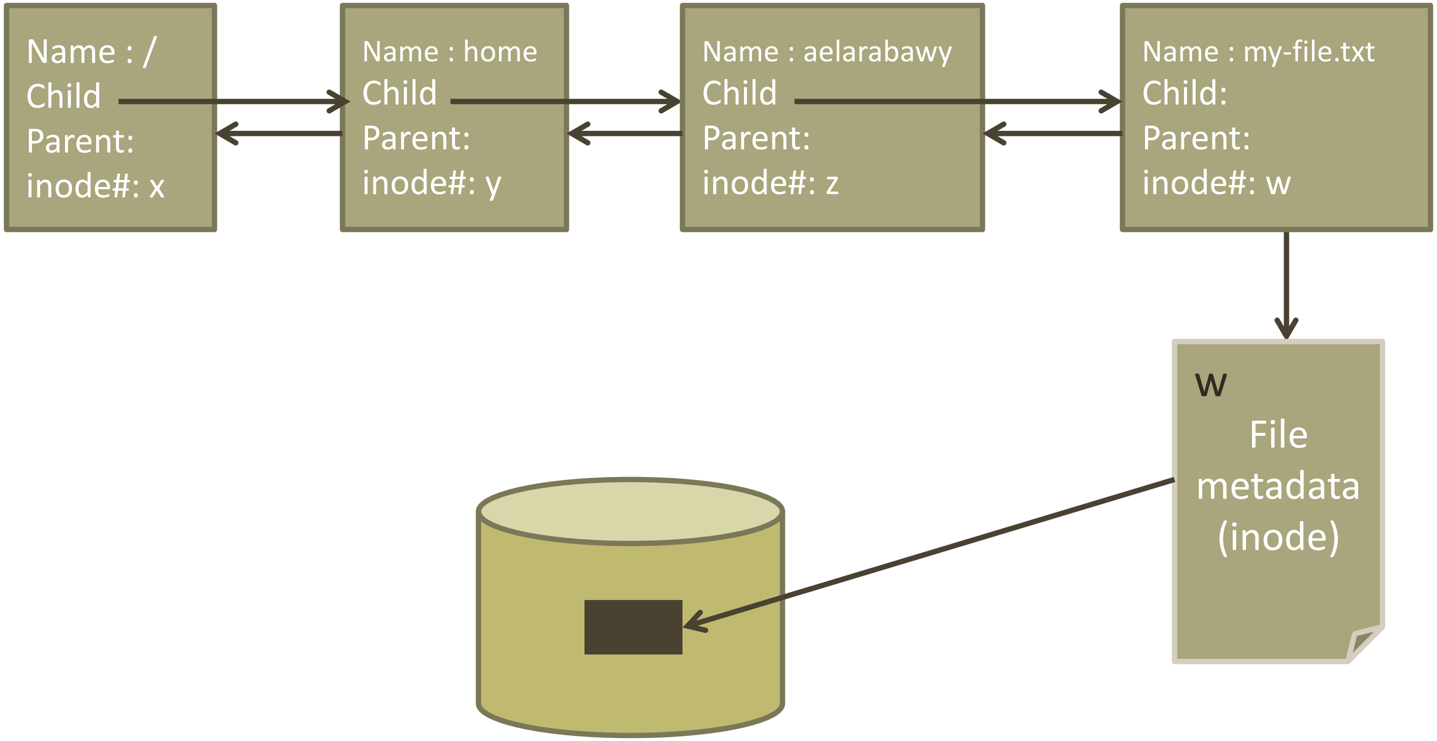
- This means that the filesystem maintains a table of inode structures (one structure per file)
- The The “inode” structure will contain all file meta-data (except its filename)
- The “inode” structure will also point to the data blocks of the file
- Each data node has a unique number across the filesystem (the inode number)
- Inode numbers are unique per filesystem (and not across the system)
- Directories are a special type of files, accordingly, they are treated the same way

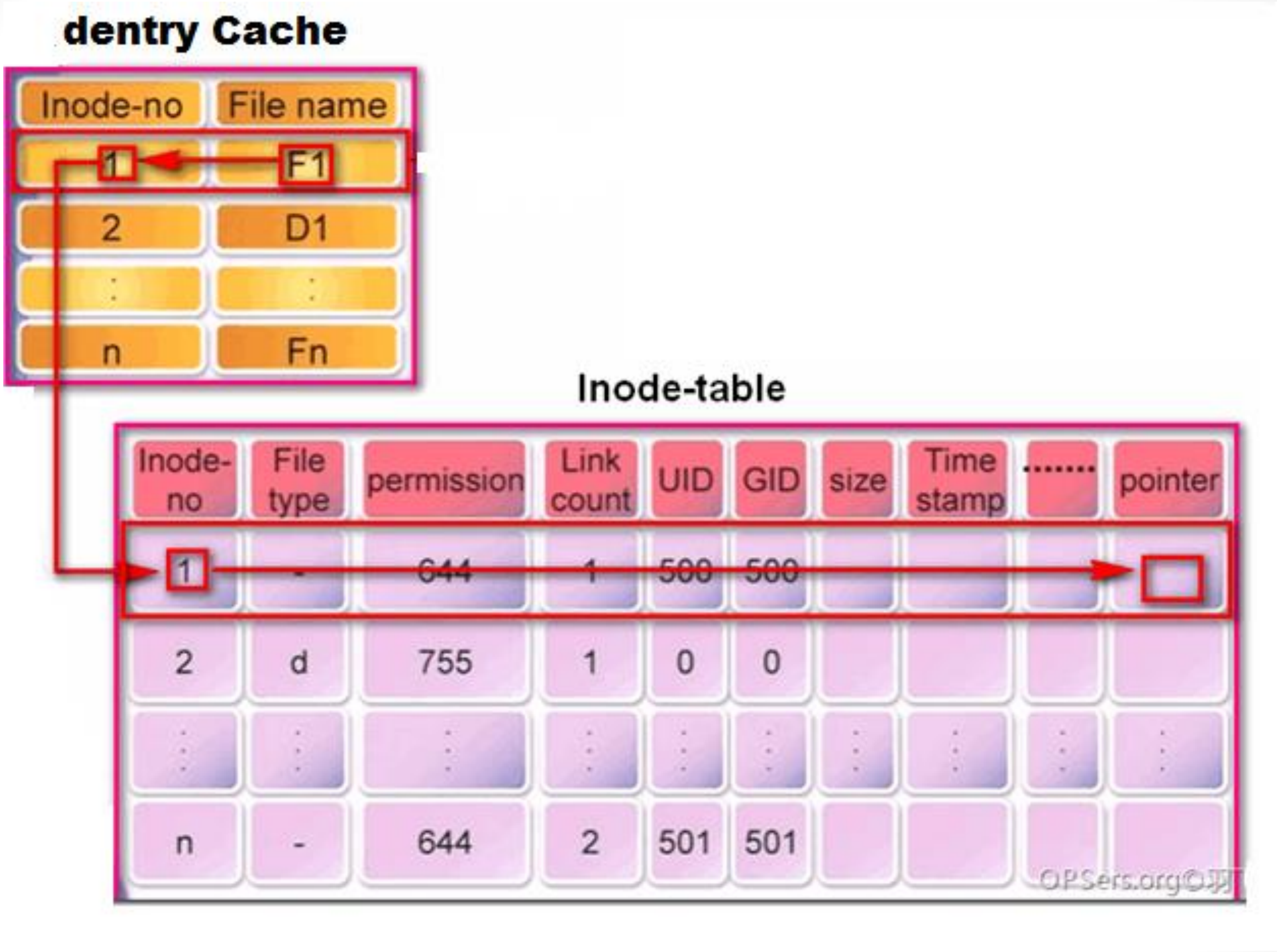
# So, What about Filenames & paths ??

- The inode structure does not have knowledge about the filename or its location
- Instead, each file or directory has another structure named “**dentry**”, this structure maps a file/directory to its “**inode#**”
- The “**dentry**” structure forms the directory tree

# Example

/home/aelarabawy/my-file.txt





**dentry Cache**

| Inode-no | File name |
|---|---|
| 1 | F1 |
| 2 | D1 |
| : | : |
| n | Fn |

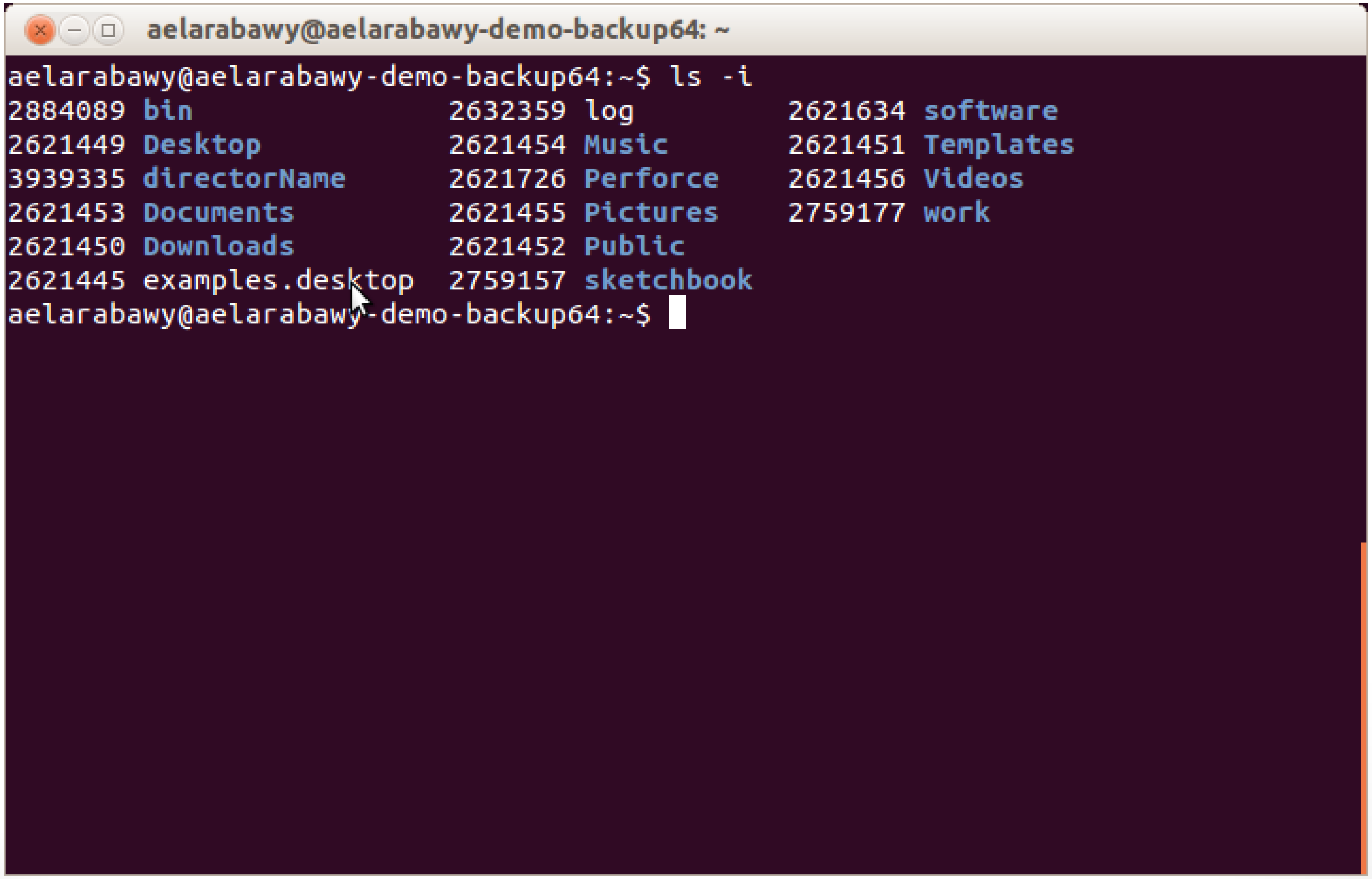
**Inode-table**

| Inode-no | File type | permission | Link count | UID | GID | size | Time stamp | ....... | pointer |
|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 644 | 1 | 500 | 500 | | | | □ |
| 2 | d | 755 | 1 | 0 | 0 | | | | |
| : | : | : | : | : | : | : | : | : | : |
| n | - | 644 | 2 | 501 | 501 | | | | |

# LINUX COMMANDS

# Listing Files/Directories (ls Command)

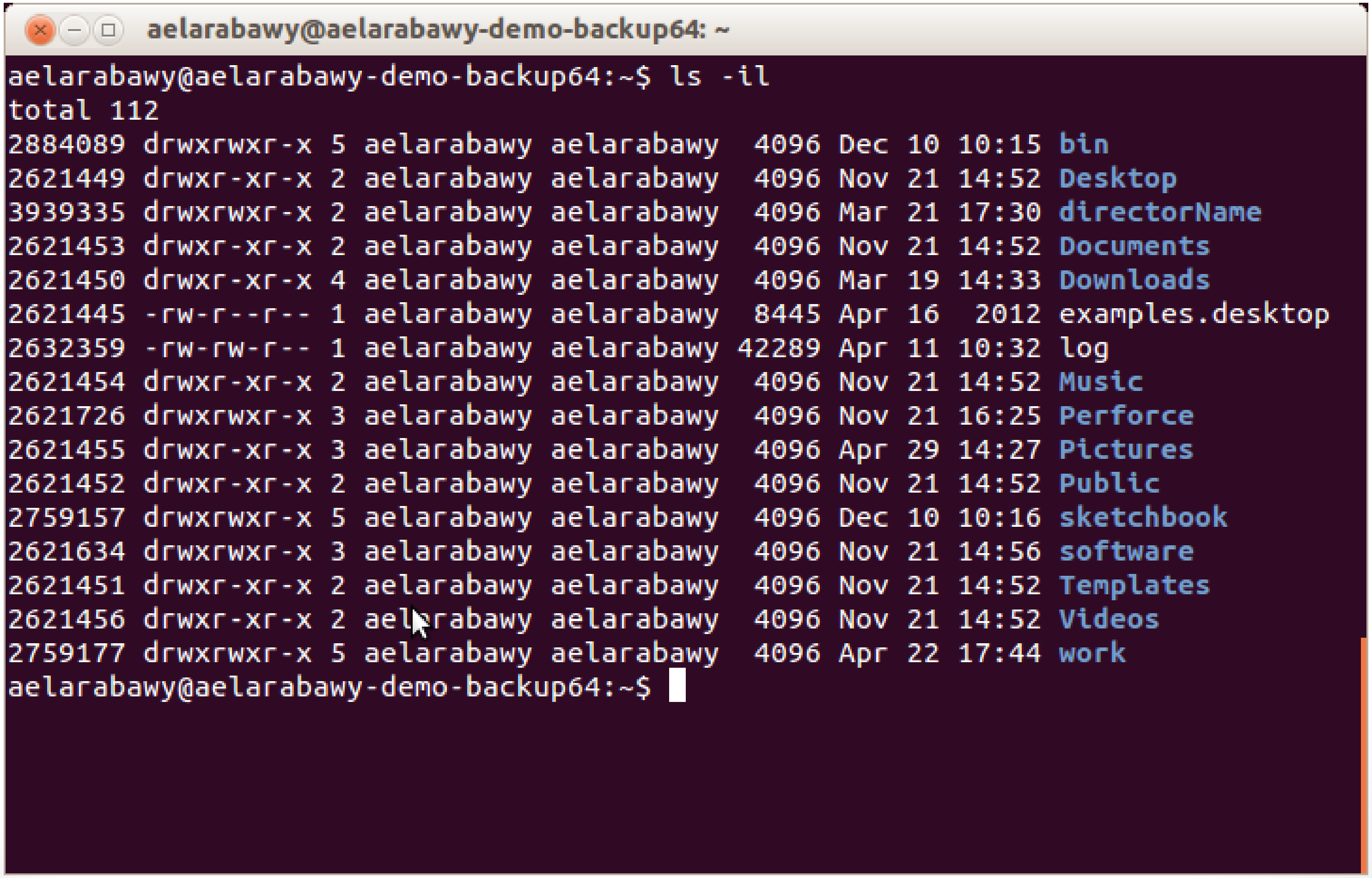
**$ ls -i     (List with showing the inode#)**



```
aelarabawy@aelarabawy-demo-backup64:~$ ls -i
2884089 bin               2632359 log          2621634 software
2621449 Desktop           2621454 Music        2621451 Templates
3939335 directorName      2621726 Perforce     2621456 Videos
2621453 Documents         2621455 Pictures     2759177 work
2621450 Downloads         2621452 Public
2621445 examples.desktop  2759157 sketchbook
aelarabawy@aelarabawy-demo-backup64:~$ 
```

# Listing Files/Directories (ls Command)

**$ ls -il (List with showing the inode# with long format)**

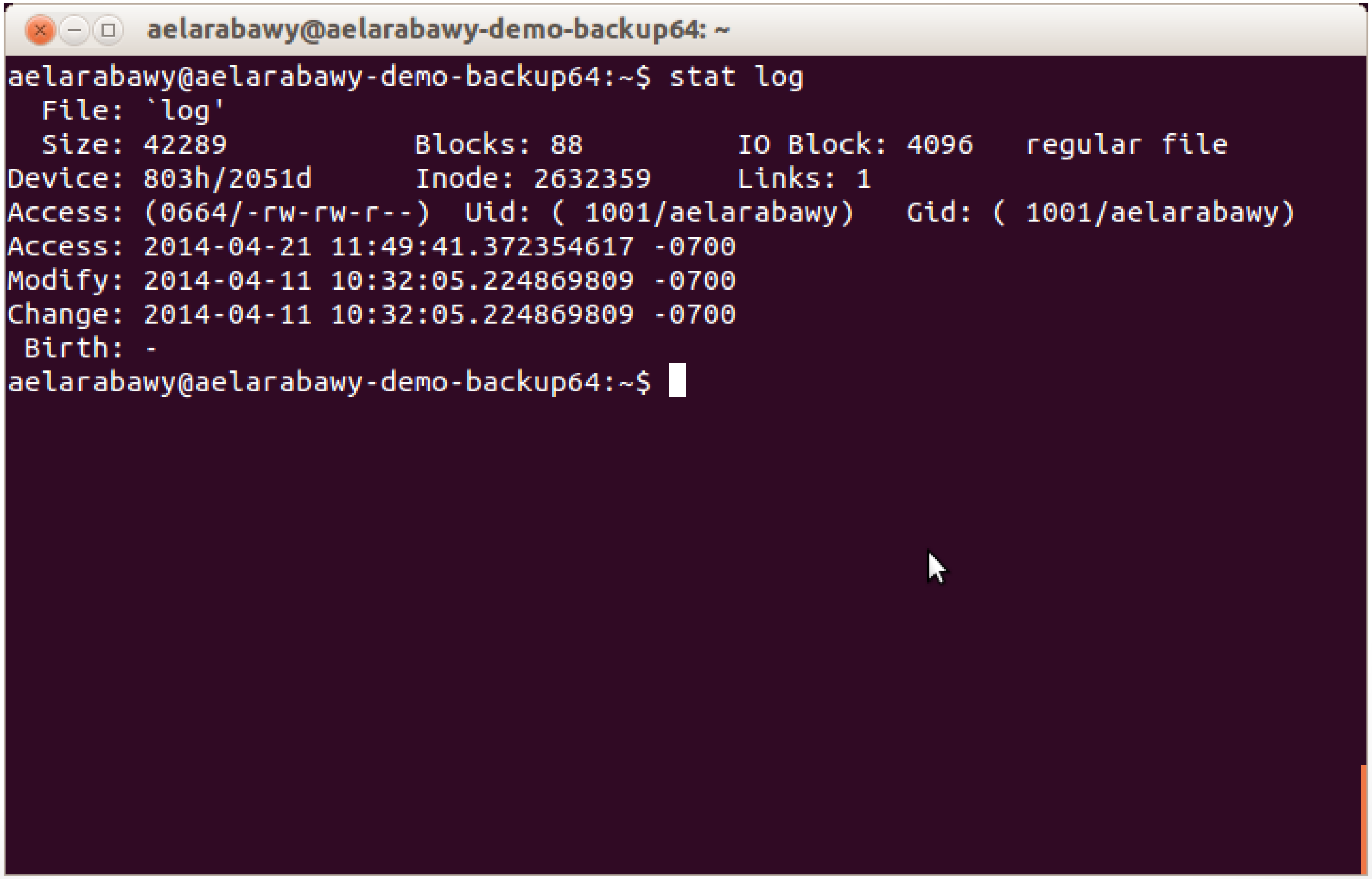


aelarabawy@aelarabawy-demo-backup64: ~

```
aelarabawy@aelarabawy-demo-backup64:~$ ls -il
total 112
2884089 drwxrwxr-x 5 aelarabawy aelarabawy  4096 Dec 10 10:15 bin
2621449 drwxr-xr-x 2 aelarabawy aelarabawy  4096 Nov 21 14:52 Desktop
3939335 drwxrwxr-x 2 aelarabawy aelarabawy  4096 Mar 21 17:30 directorName
2621453 drwxr-xr-x 2 aelarabawy aelarabawy  4096 Nov 21 14:52 Documents
2621450 drwxr-xr-x 4 aelarabawy aelarabawy  4096 Mar 19 14:33 Downloads
2621445 -rw-r--r-- 1 aelarabawy aelarabawy  8445 Apr 16  2012 examples.desktop
2632359 -rw-rw-r-- 1 aelarabawy aelarabawy 42289 Apr 11 10:32 log
2621454 drwxr-xr-x 2 aelarabawy aelarabawy  4096 Nov 21 14:52 Music
2621726 drwxrwxr-x 3 aelarabawy aelarabawy  4096 Nov 21 16:25 Perforce
2621455 drwxr-xr-x 3 aelarabawy aelarabawy  4096 Apr 29 14:27 Pictures
2621452 drwxr-xr-x 2 aelarabawy aelarabawy  4096 Nov 21 14:52 Public
2759157 drwxrwxr-x 5 aelarabawy aelarabawy  4096 Dec 10 10:16 sketchbook
2621634 drwxrwxr-x 3 aelarabawy aelarabawy  4096 Nov 21 14:56 software
2621451 drwxr-xr-x 2 aelarabawy aelarabawy  4096 Nov 21 14:52 Templates
2621456 drwxr-xr-x 2 aelarabawy aelarabawy  4096 Nov 21 14:52 Videos
2759177 drwxrwxr-x 5 aelarabawy aelarabawy  4096 Apr 22 17:44 work
aelarabawy@aelarabawy-demo-backup64:~$ 
```

# Showing File Status (stat Command)

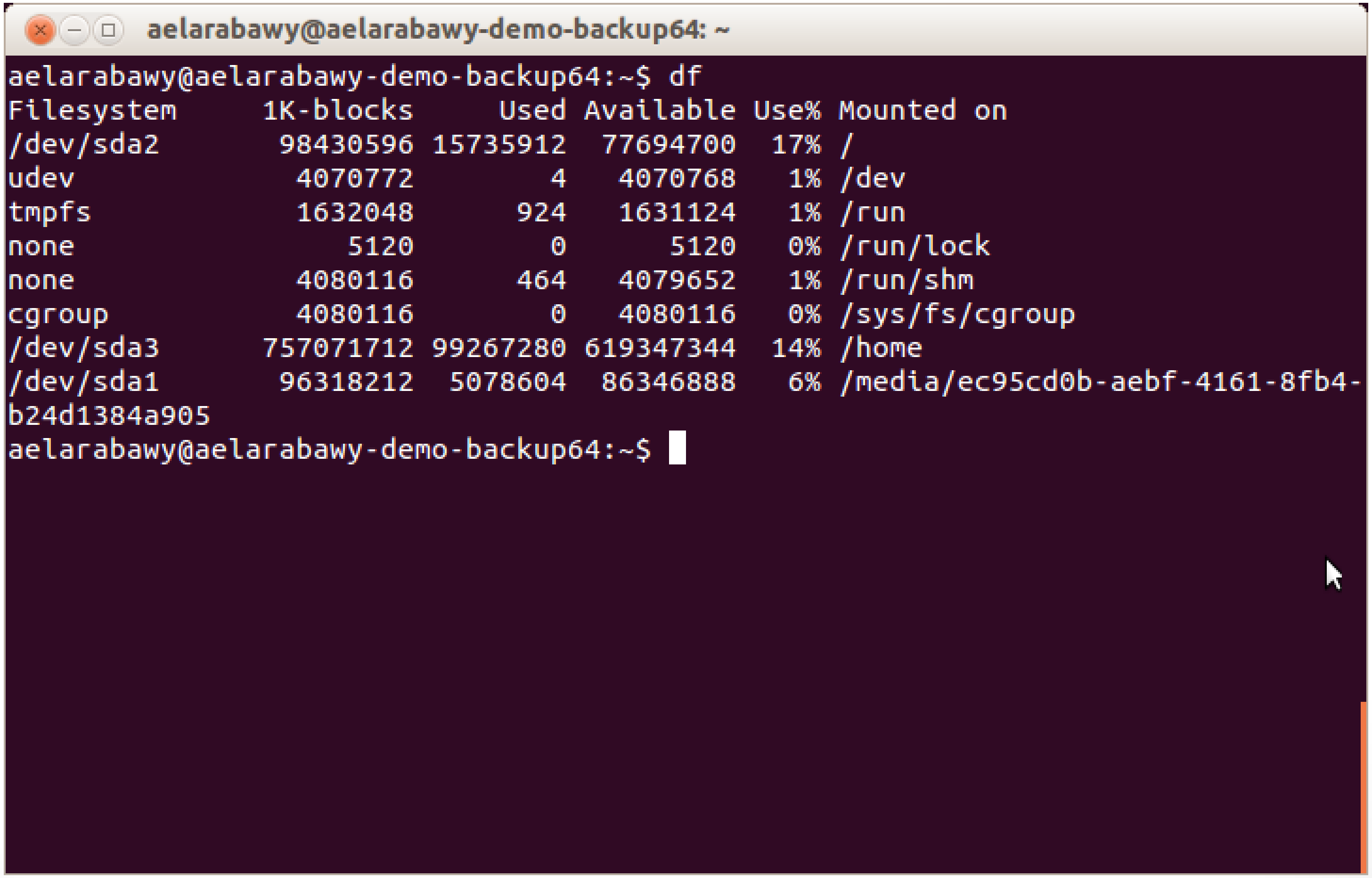
**$ stat (Show File Status info)**



```
aelarabawy@aelarabawy-demo-backup64:~$ stat log
  File: `log'
  Size: 42289           Blocks: 88         IO Block: 4096   regular file
Device: 803h/2051d      Inode: 2632359     Links: 1
Access: (0664/-rw-rw-r--)  Uid: ( 1001/aelarabawy)   Gid: ( 1001/aelarabawy)
Access: 2014-04-21 11:49:41.372354617 -0700
Modify: 2014-04-11 10:32:05.224869809 -0700
Change: 2014-04-11 10:32:05.224869809 -0700
 Birth: -
aelarabawy@aelarabawy-demo-backup64:~$ 
```

# Show FileSystem Disk Space Usage (df Comand)

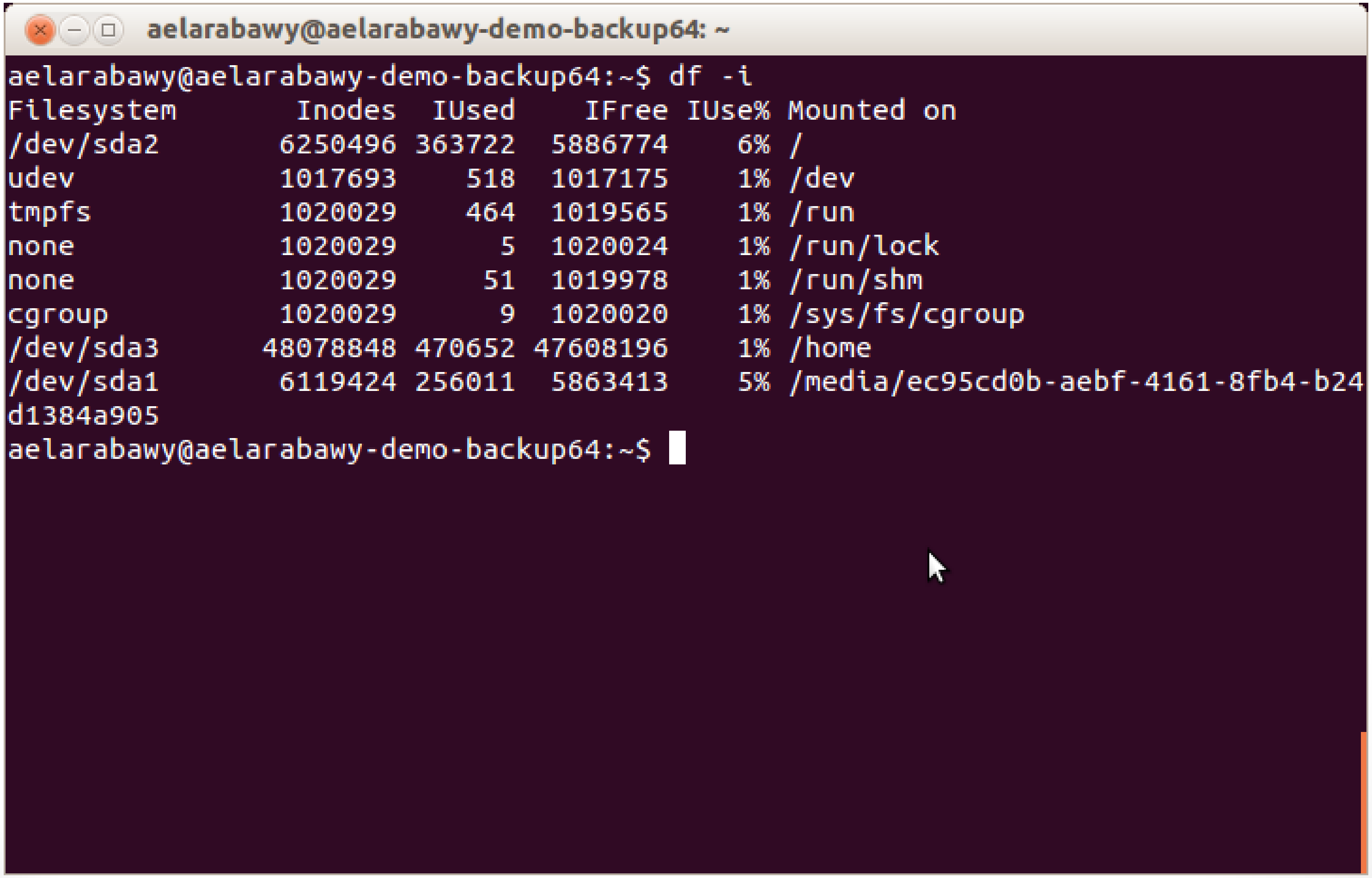
**$ df  (Show FileSystem Disk Space Usage)**



```
aelarabawy@aelarabawy-demo-backup64:~$ df
Filesystem     1K-blocks     Used Available Use% Mounted on
/dev/sda2       98430596 15735912  77694700  17% /
udev             4070772        4   4070768   1% /dev
tmpfs            1632048      924   1631124   1% /run
none                5120        0      5120   0% /run/lock
none             4080116      464   4079652   1% /run/shm
cgroup           4080116        0   4080116   0% /sys/fs/cgroup
/dev/sda3      757071712 99267280 619347344  14% /home
/dev/sda1       96318212  5078604  86346888   6% /media/ec95cd0b-aebf-4161-8fb4-
b24d1384a905
aelarabawy@aelarabawy-demo-backup64:~$ 
```

# Show FileSystem Disk Space Usage (df Comand)

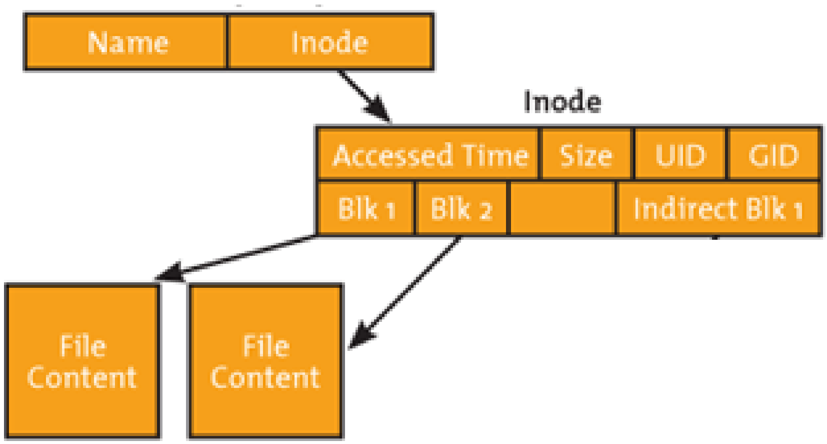
**$ df -i (Show FileSystem inode Usage)**



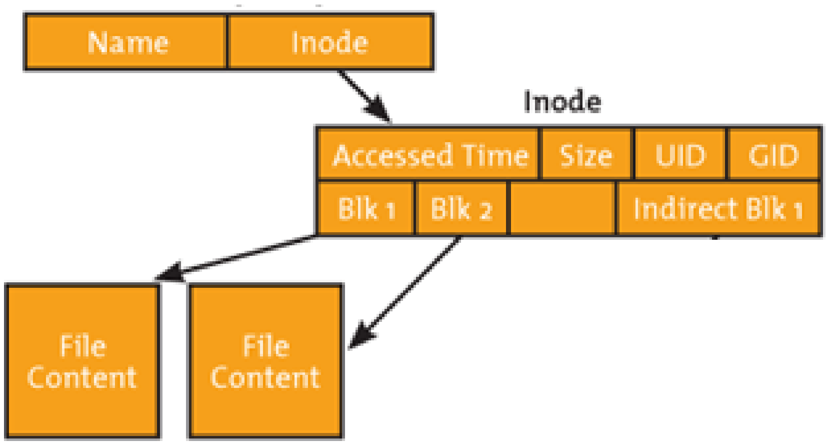
```
aelarabawy@aelarabawy-demo-backup64:~$ df -i
Filesystem        Inodes  IUsed    IFree IUse% Mounted on
/dev/sda2        6250496 363722  5886774    6% /
udev             1017693    518  1017175    1% /dev
tmpfs            1020029    464  1019565    1% /run
none             1020029      5  1020024    1% /run/lock
none             1020029     51  1019978    1% /run/shm
cgroup           1020029      9  1020020    1% /sys/fs/cgroup
/dev/sda3       48078848 470652 47608196    1% /home
/dev/sda1        6119424 256011  5863413    5% /media/ec95cd0b-aebf-4161-8fb4-b24
d1384a905
aelarabawy@aelarabawy-demo-backup64:~$ 
```

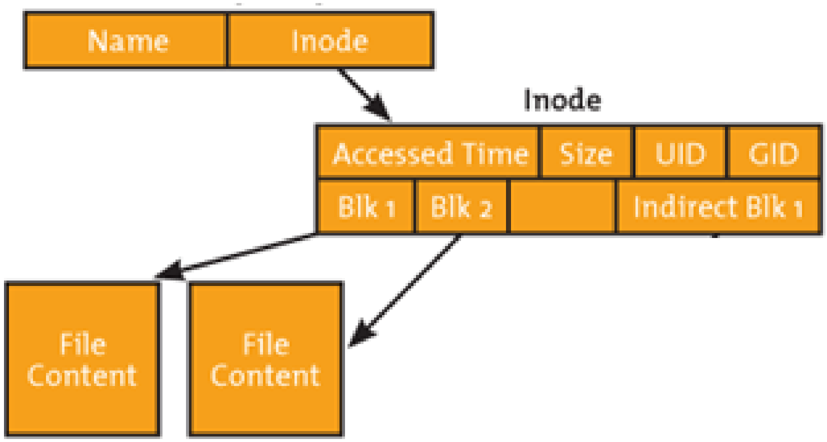
# FILE OPERATIONS

# Copying a File

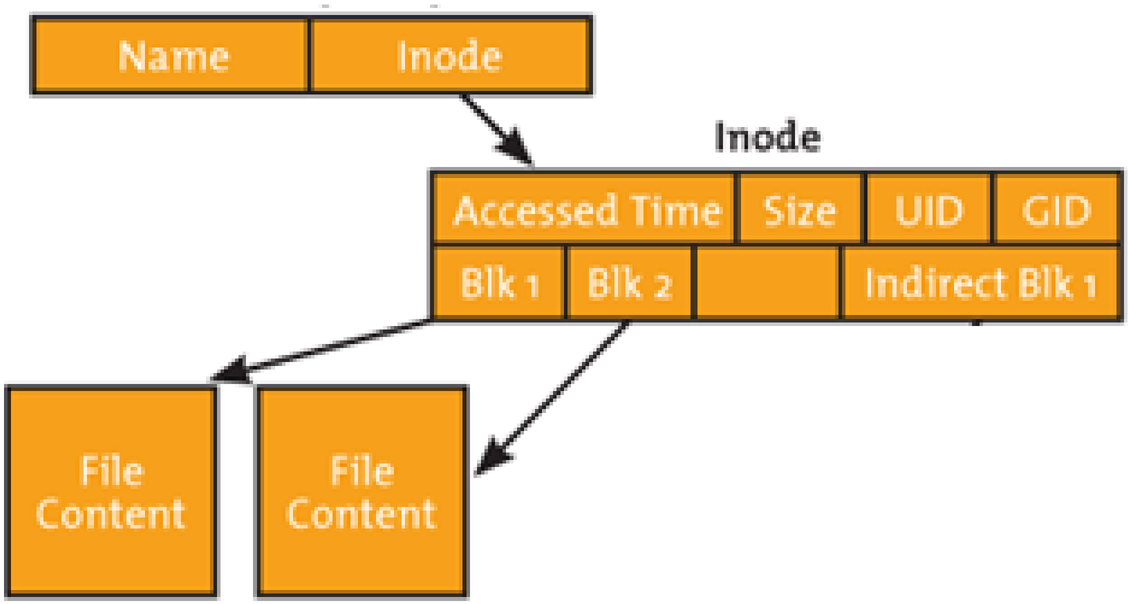


# Copying a File

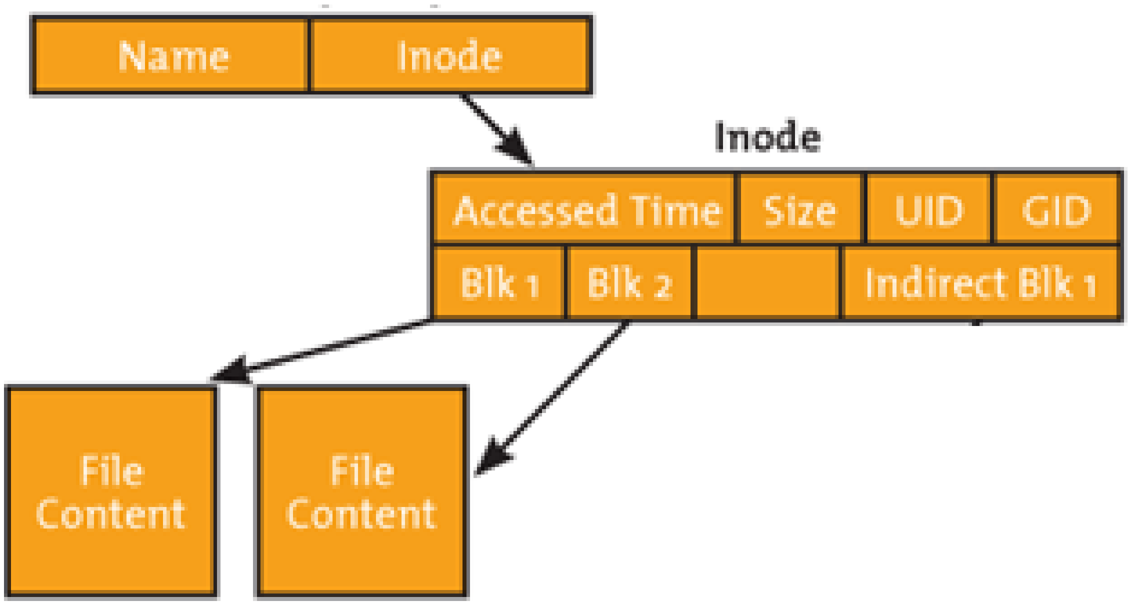




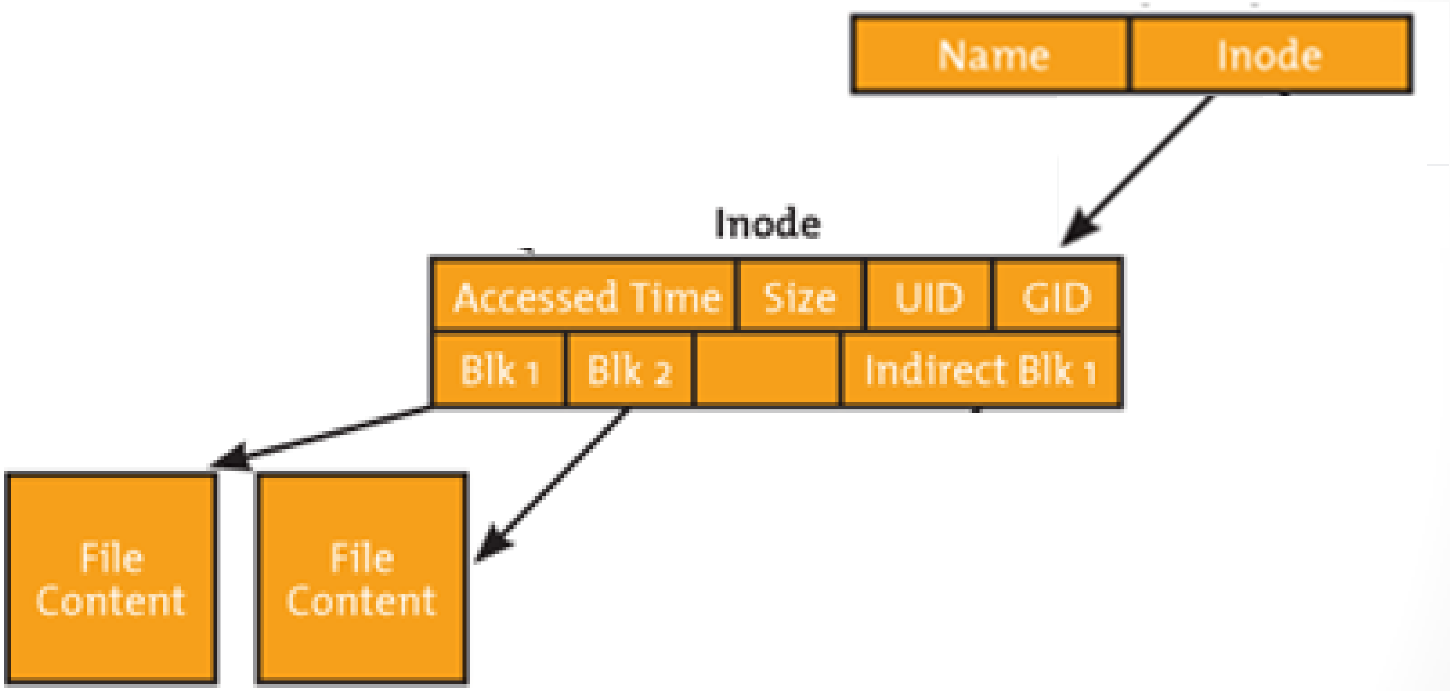
# Renaming a File



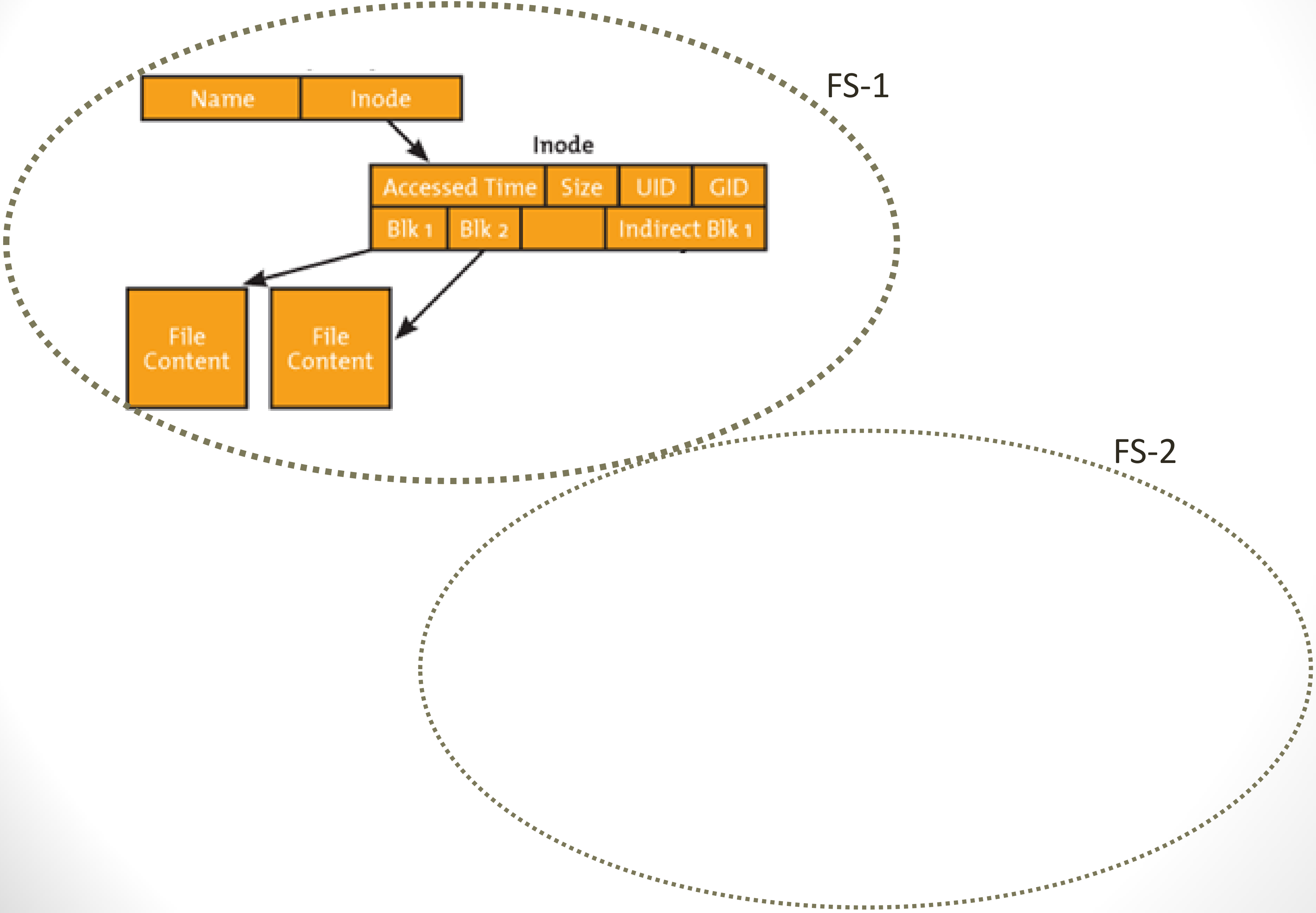
# Moving a File (Within Same FS)



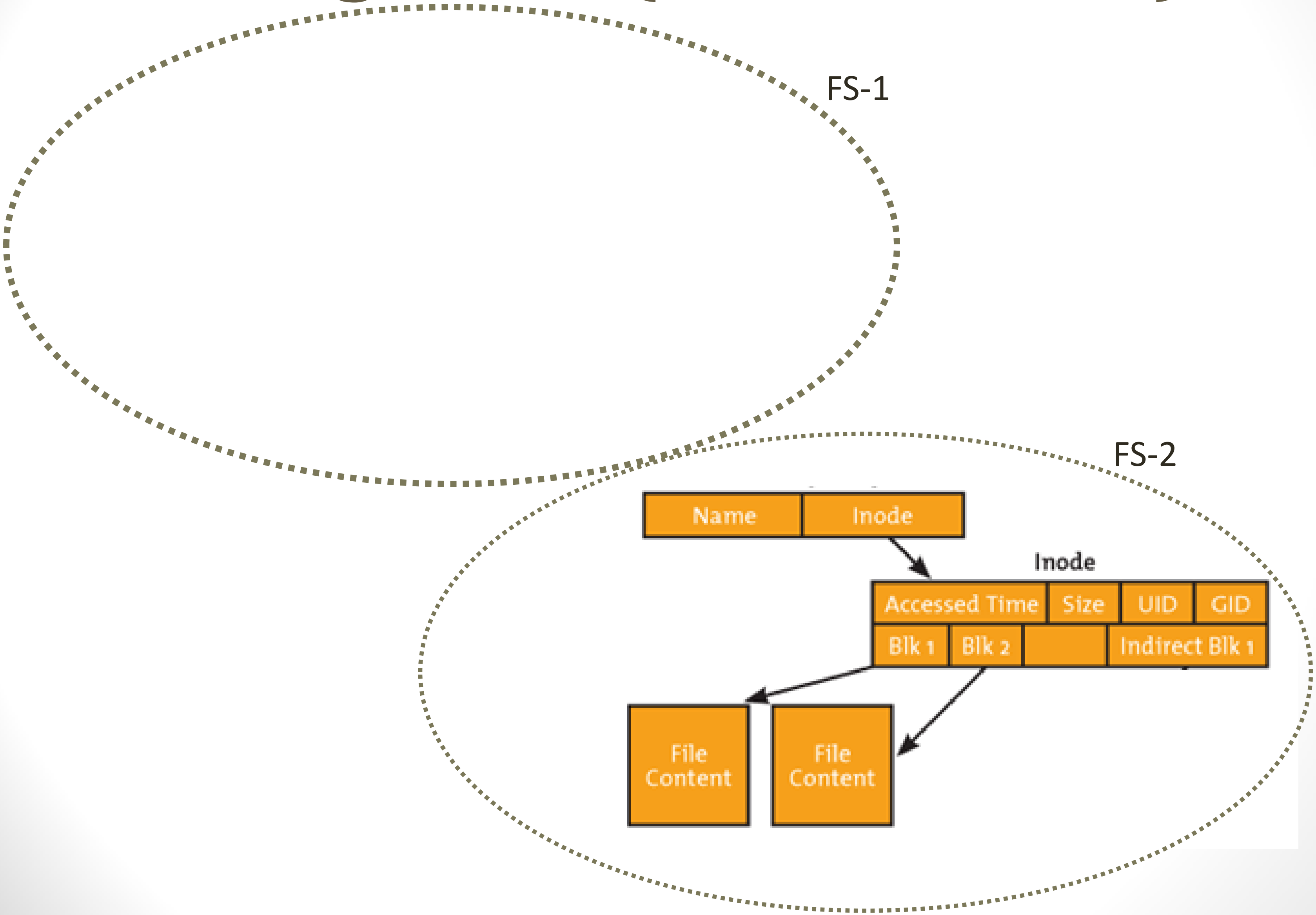
# Moving a File (Within Same FS)



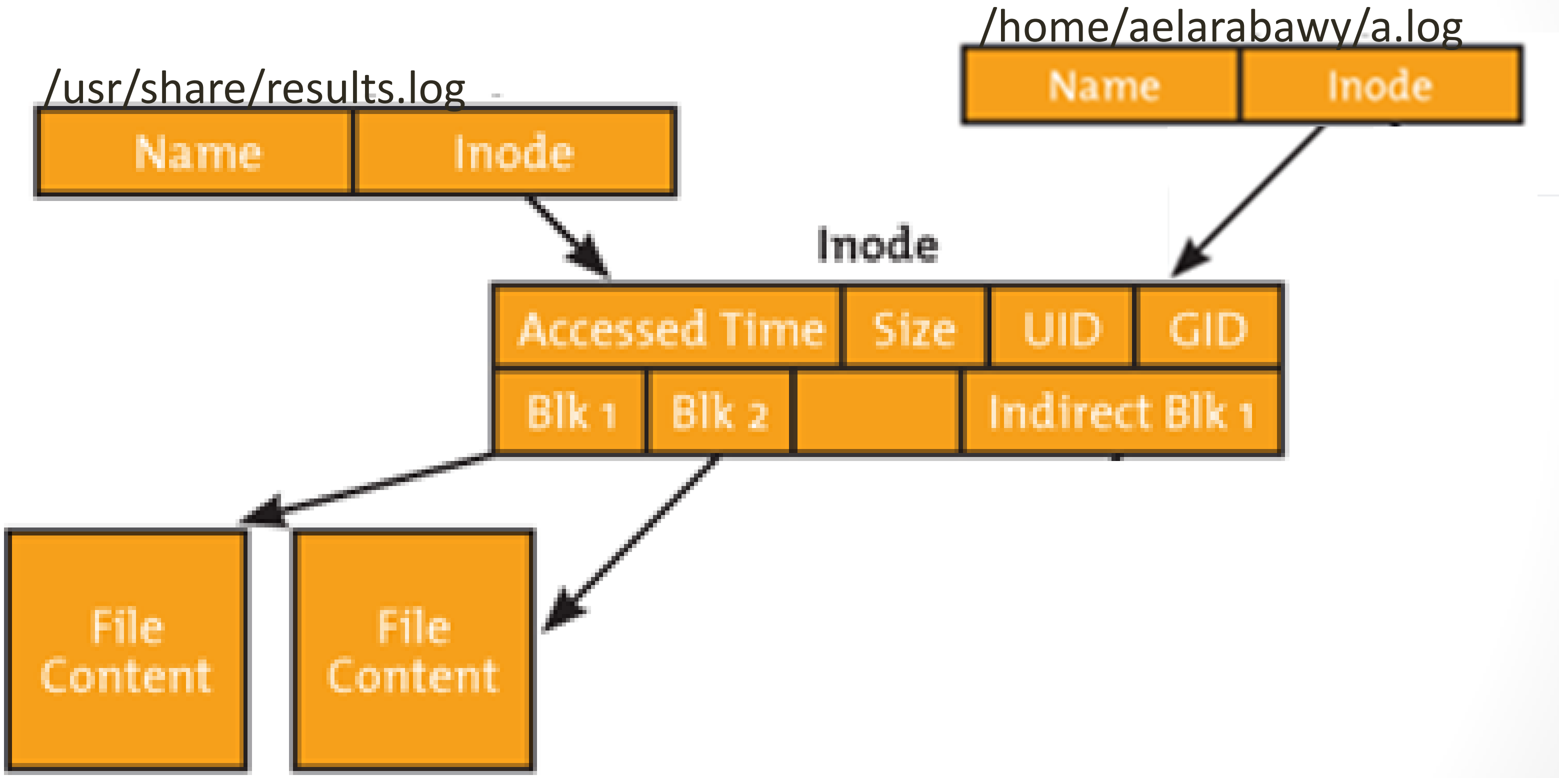
# Moving a File (Between FSs)



# Moving a File (Between FSs)



# LINKING FILES

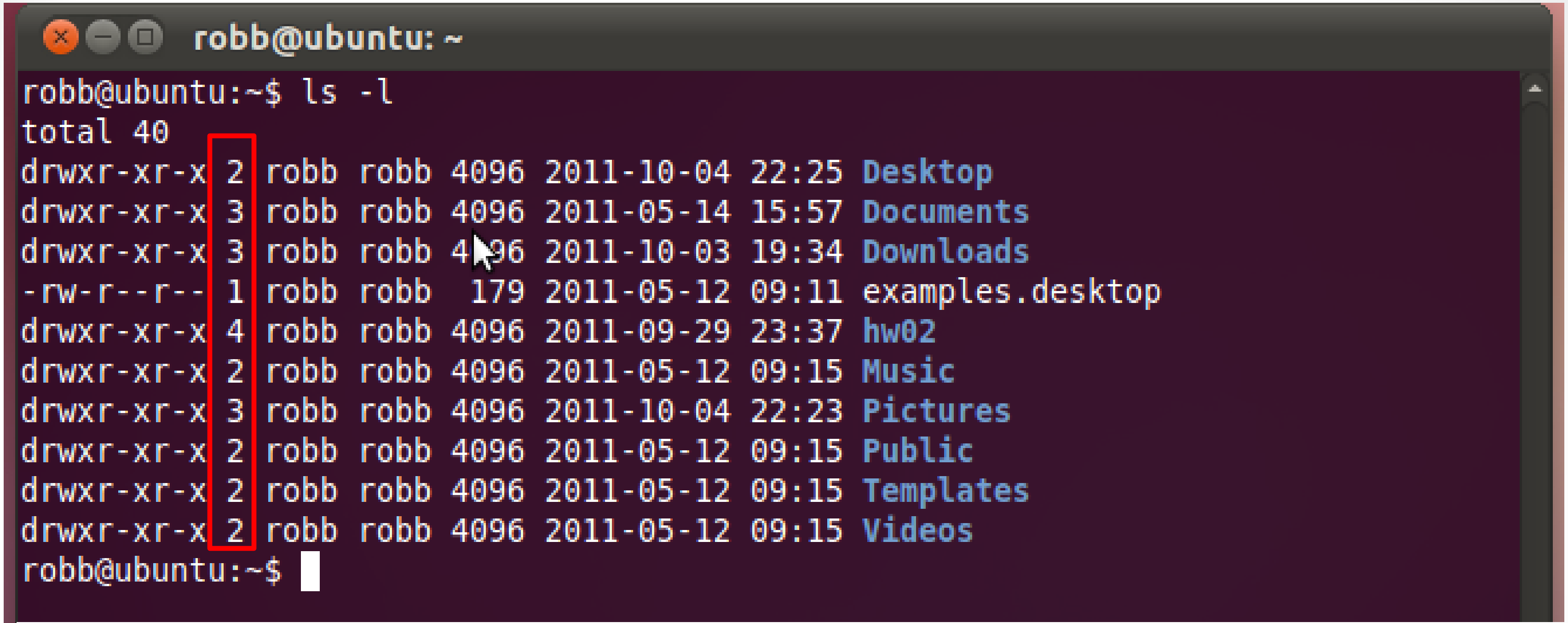


/usr/share/results.log
Name
Inode
/home/aelarabawy/a.log
Name
Inode
Inode
Accessed Time
Size
UID
GID
Blk 1
Blk 2
Indirect Blk 1
File Content
File Content

# Hard Link

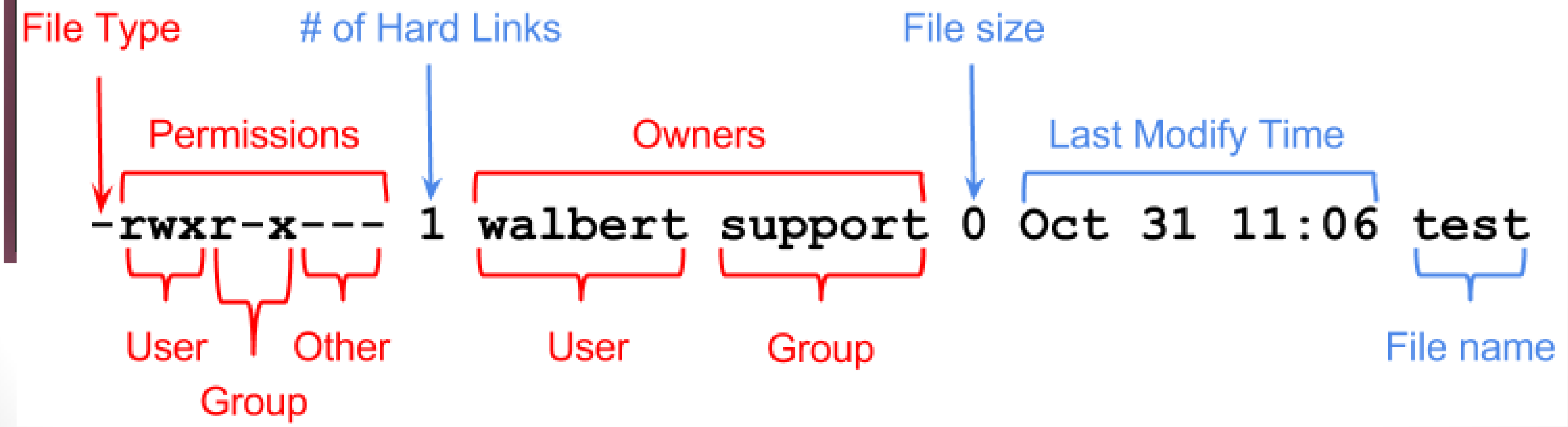
# Hard Links

- The decision of not including the filename and path in the "inode" structure was to enable the use of hard links
- Hard links were introduced from the early days of Unix
- A hard link
  - Not a new file
  - Same file content
  - Same inode
  - Just an additional "dentry" with a different filename/path, but with the same inode#
- This is useful if we need to have the same file with two names, or in two locations



robb@ubuntu: ~

```
robb@ubuntu:~$ ls -l
total 40
drwxr-xr-x 2 robb robb 4096 2011-10-04 22:25 Desktop
drwxr-xr-x 3 robb robb 4096 2011-05-14 15:57 Documents
drwxr-xr-x 3 robb robb 4096 2011-10-03 19:34 Downloads
-rw-r--r-- 1 robb robb  179 2011-05-12 09:11 examples.desktop
drwxr-xr-x 4 robb robb 4096 2011-09-29 23:37 hw02
drwxr-xr-x 2 robb robb 4096 2011-05-12 09:15 Music
drwxr-xr-x 3 robb robb 4096 2011-10-04 22:23 Pictures
drwxr-xr-x 2 robb robb 4096 2011-05-12 09:15 Public
drwxr-xr-x 2 robb robb 4096 2011-05-12 09:15 Templates
drwxr-xr-x 2 robb robb 4096 2011-05-12 09:15 Videos
robb@ubuntu:~$
```



File Type

# of Hard Links

File size

Permissions

Owners

Last Modify Time

```
-rwxr-x--- 1 walbert support 0 Oct 31 11:06 test
```

User

Other

Group

User

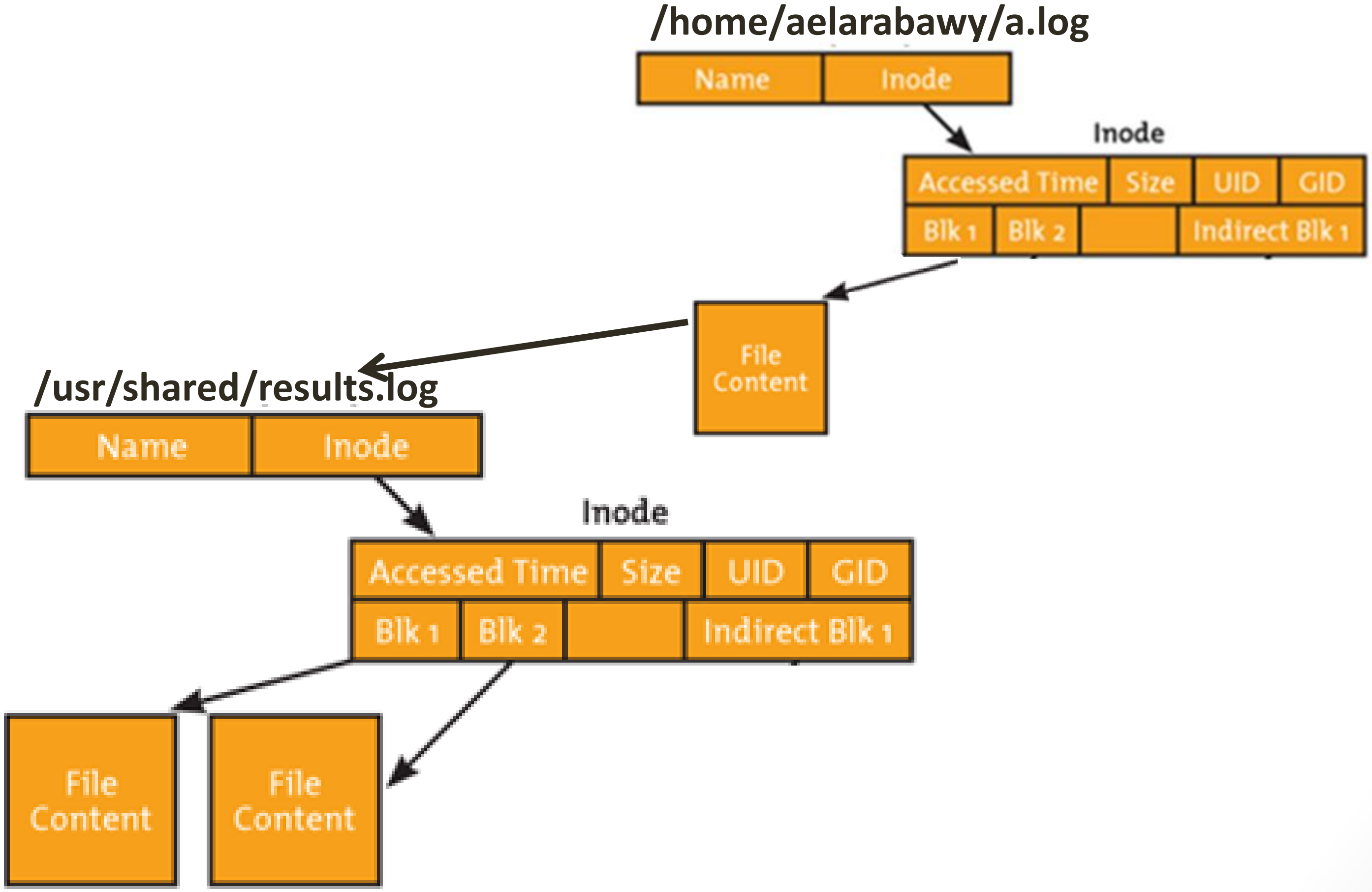
Group

File name

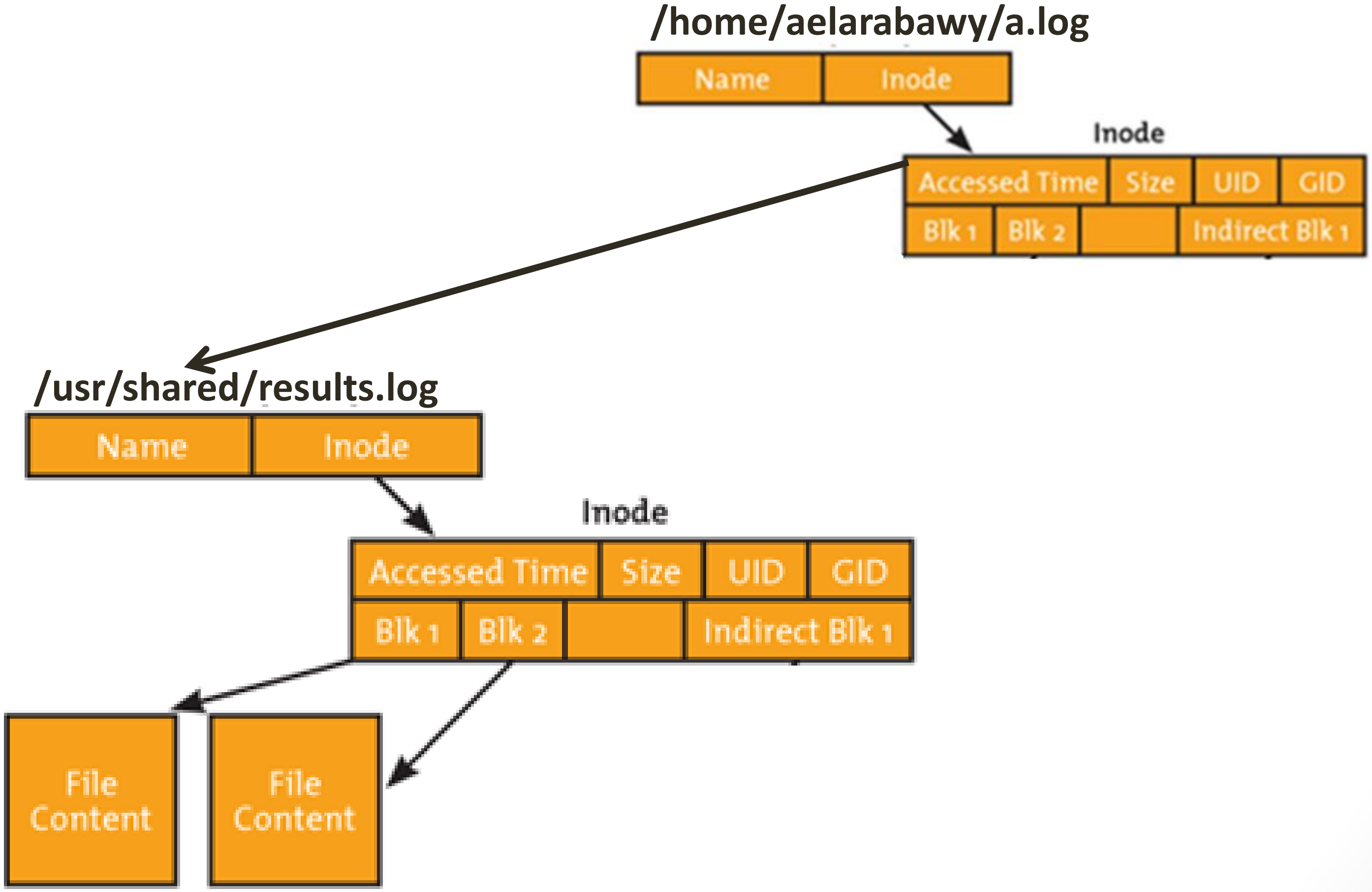
# However,

- Hard links are not very common these days, they have some limitations,
  - Only applicable for files, not used for directories
    - After implementing it for directories, a security hole was found
    - Can cause loops of links which result in system faults
    - So it was disabled in latest releases
  - Does not work across filesystems
    - We just link using the inode#
    - But inode# is only unique within the same filesystem
    - Hence, we can not link to a file in a different filesystem
    - This is very limiting, specially Linux merges all the FS in a unified tree

# Symbolic Links



# Symbolic Links

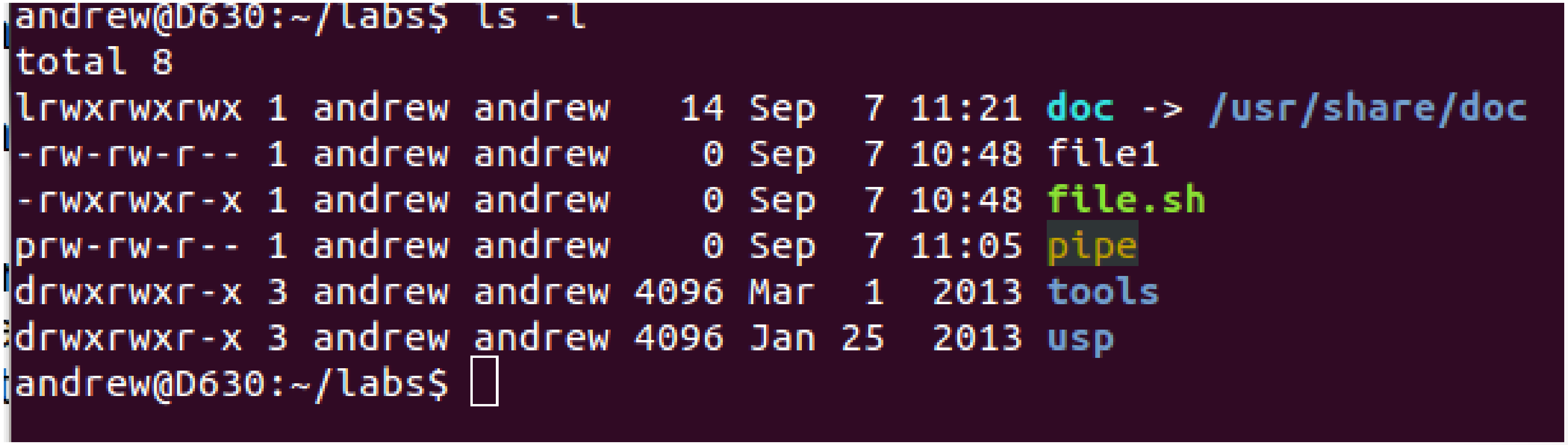


# Symbolic Links

- A symbolic link is introduced to fix the problems of Hard Links
- A symbolic Link is not just a dentry structure; it is a file with an inode structre
- The inode structure
    - The type is set to ‘l’ for a symbolic link
- Two types of Implementation:
    - Slow Symbolic Links:
        - The data block of the new file include the path of the file it is linking to
    - Fast Symbolic Links:
        - A field in the inode points to the path and name of the file/directory it is pointing to
        - Faster, no need to read the data block
        - Not possible if the path is too long to fit in the inode structure
- Since a symbolic link it has its own inode, with an obvious indication that it is a link,
    - Some commands is able to treat it differently
    - Avoid the security hole in hard links with linking directories
    - We can link to a file/directory in a different file system

# Symbolic Links

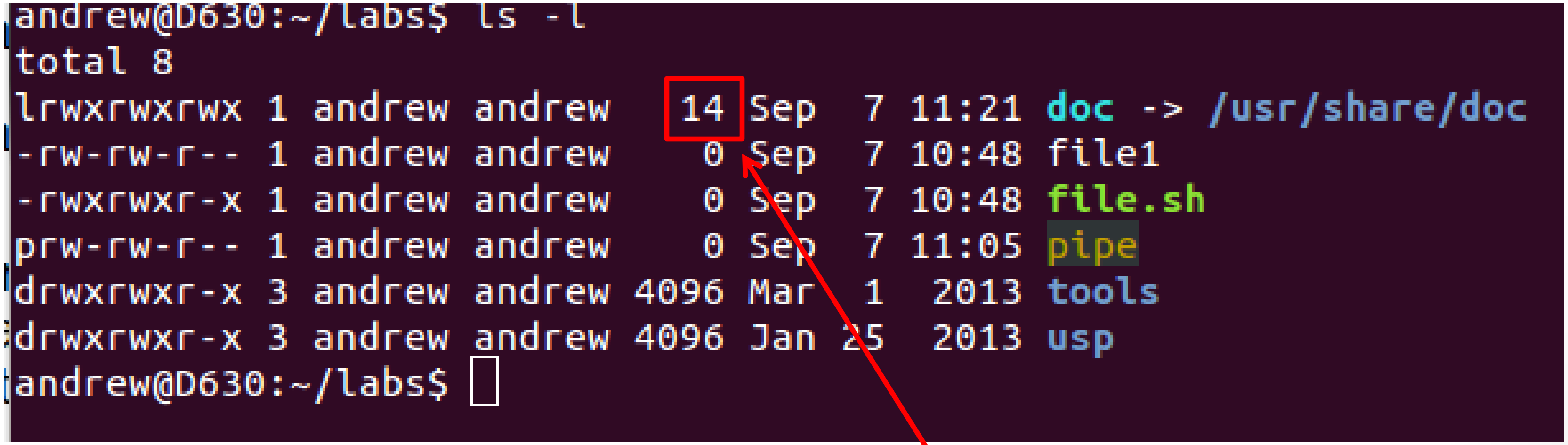
- Symbolic links are like shortcuts in windows
- You can have a symbolic link to a file or a folder



```
andrew@D630:~/labs$ ls -l
total 8
lrwxrwxrwx 1 andrew andrew   14 Sep  7 11:21 doc -> /usr/share/doc
-rw-rw-r-- 1 andrew andrew    0 Sep  7 10:48 file1
-rwxrwxr-x 1 andrew andrew    0 Sep  7 10:48 file.sh
prw-rw-r-- 1 andrew andrew    0 Sep  7 11:05 pipe
drwxrwxr-x 3 andrew andrew 4096 Mar  1  2013 tools
drwxrwxr-x 3 andrew andrew 4096 Jan 25  2013 usp
andrew@D630:~/labs$ 
```

# Symbolic Links

- Symbolic links are like shortcuts in windows
- You can have a symbolic link to a file or a folder

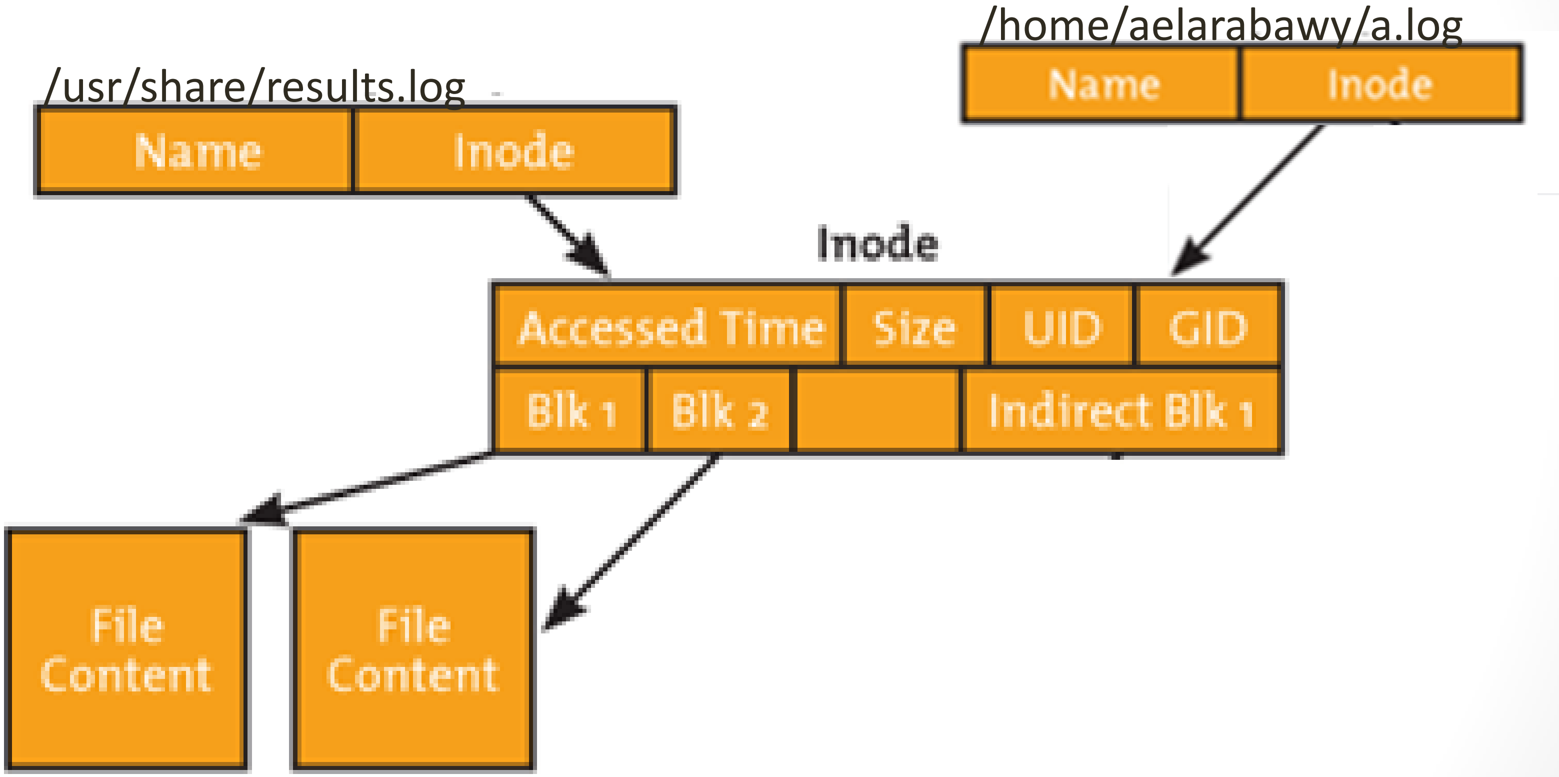


```
andrew@D630:~/labs$ ls -l
total 8
lrwxrwxrwx 1 andrew andrew   14 Sep  7 11:21 doc -> /usr/share/doc
-rw-rw-r-- 1 andrew andrew    0 Sep  7 10:48 file1
-rwxrwxr-x 1 andrew andrew    0 Sep  7 10:48 file.sh
prw-rw-r-- 1 andrew andrew    0 Sep  7 11:05 pipe
drwxrwxr-x 3 andrew andrew 4096 Mar  1  2013 tools
drwxrwxr-x 3 andrew andrew 4096 Jan 25  2013 usp
andrew@D630:~/labs$ 
```

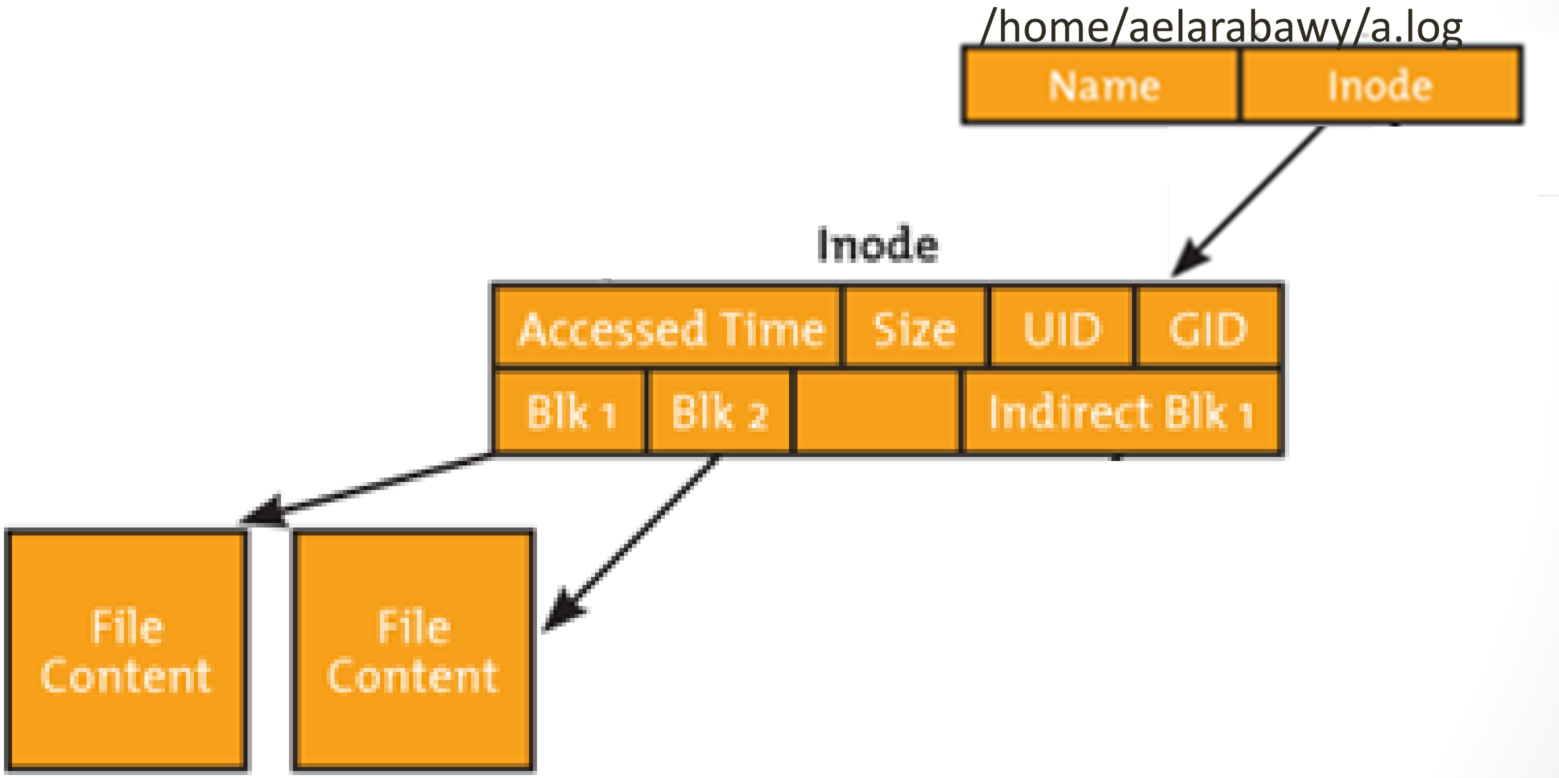
**Question:**
**Why do you think the size of “doc” is 14 bytes ???**

# DELETING FILES & LINKS

# Hard Links

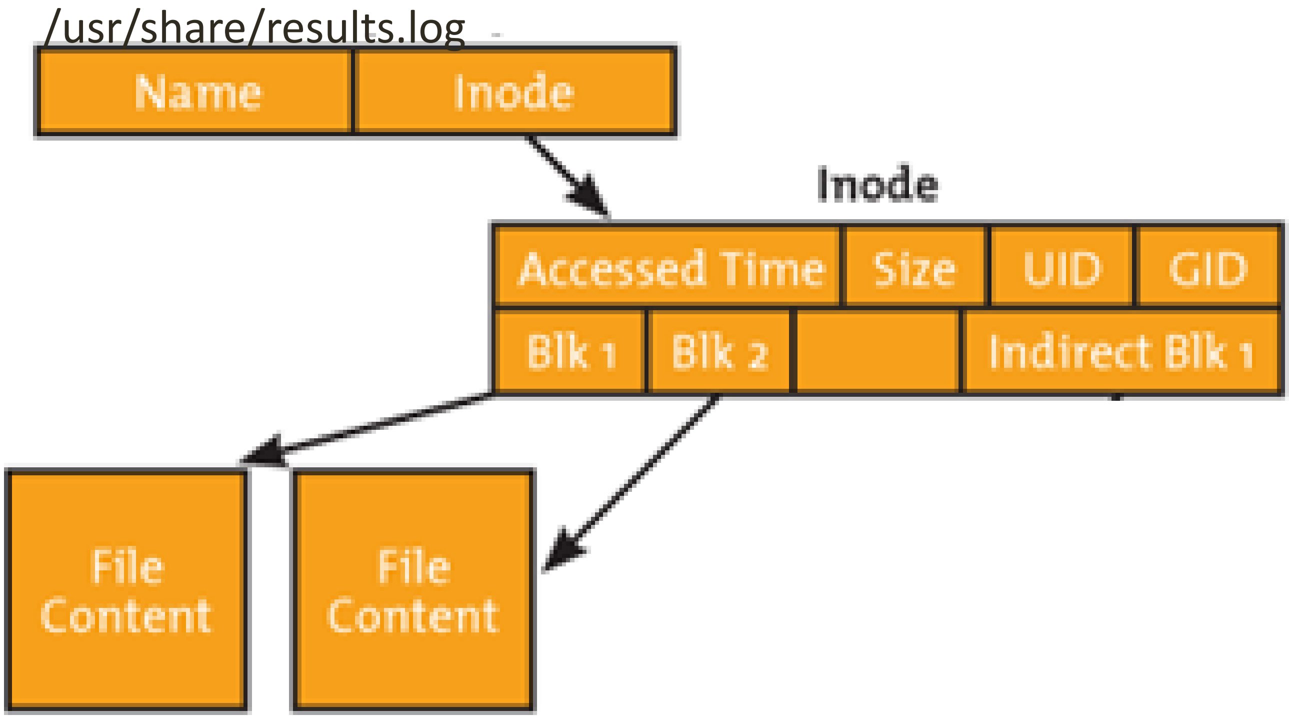

/home/aelarabawy/a.log
Name
Inode
/usr/share/results.log
Name
Inode
Inode
Accessed Time
Size
UID
GID
Blk 1
Blk 2
Indirect Blk 1
File Content
File Content

# Hard Links



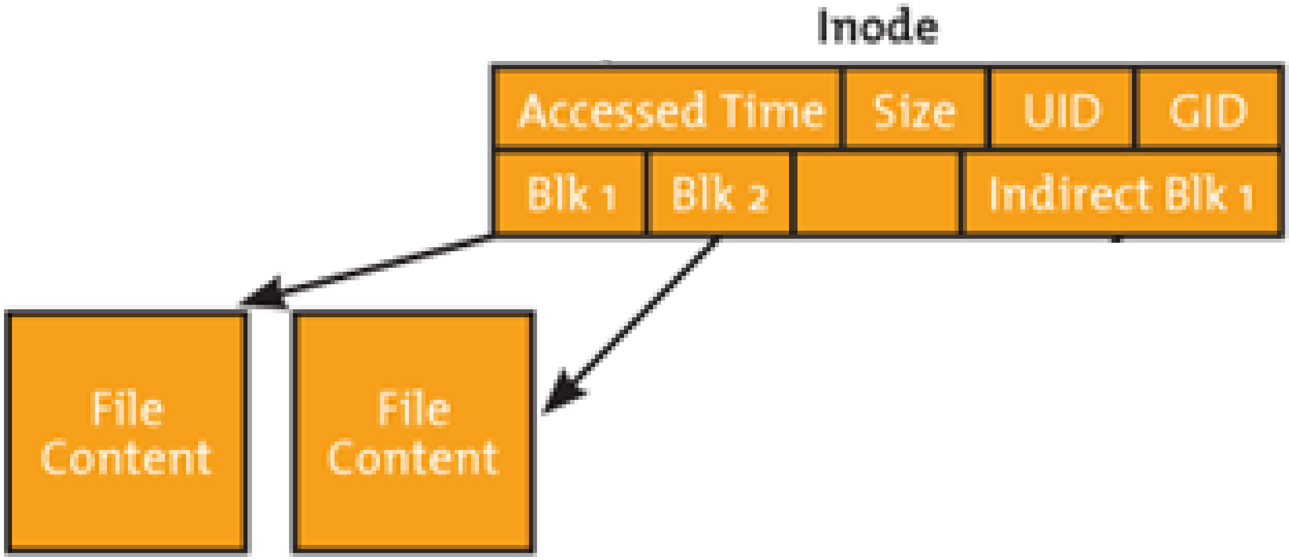
```
$ rm /usr/share/results.log
```

# Hard Links



***$ rm ~/a.log***

# Hard Links

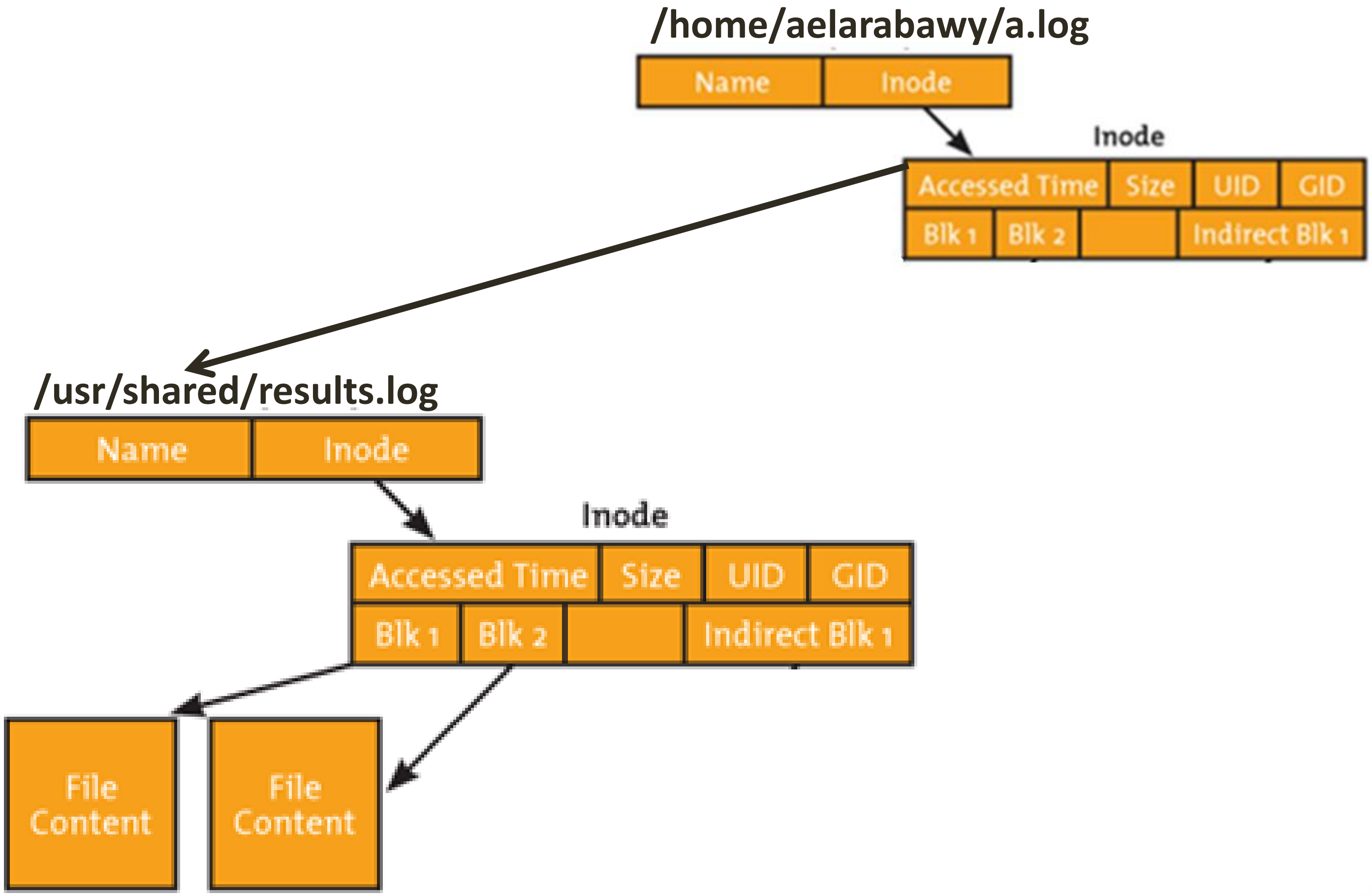


```
$ rm /usr/share/results.log
$ rm ~/a.log
```

# Hard Links

```
$ rm /usr/share/results.log
$ rm ~/a.log
```

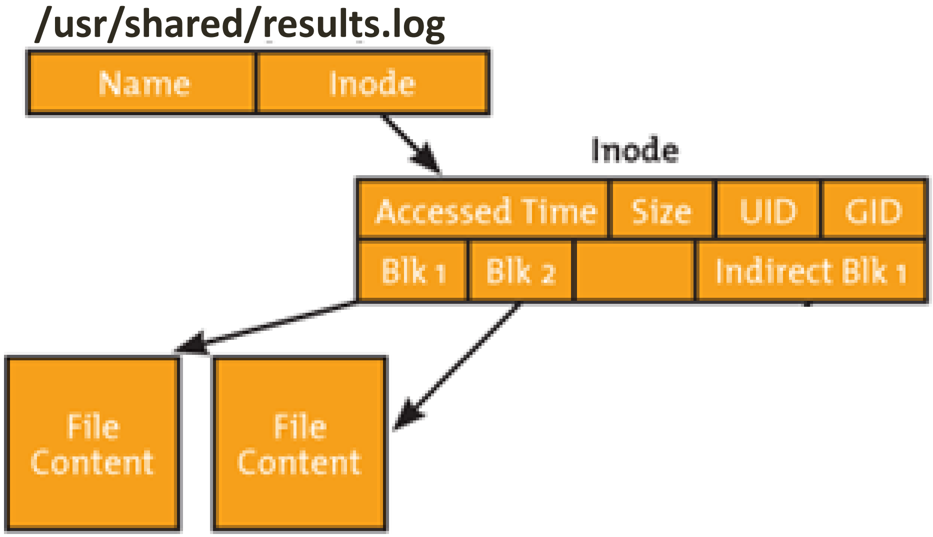
# Symbolic Links



/home/aelarabawy/a.log

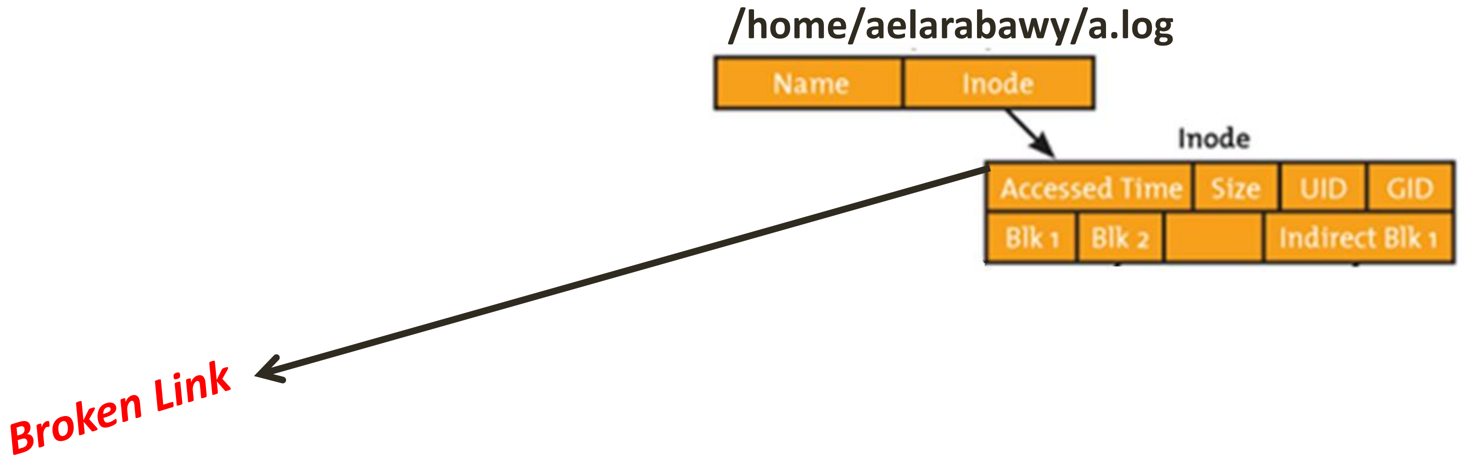
/usr/shared/results.log

# Symbolic Links



***$ rm ~/a.log***

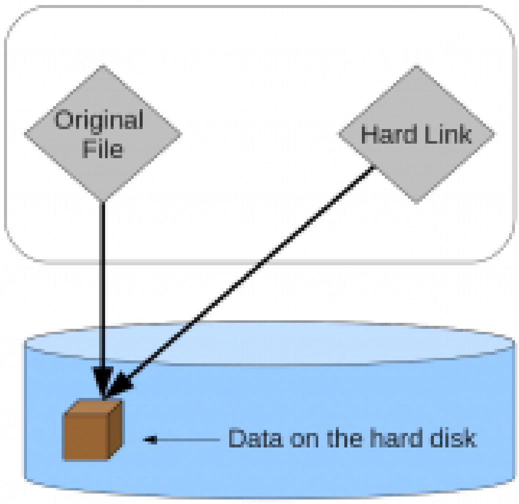
# Symbolic Links



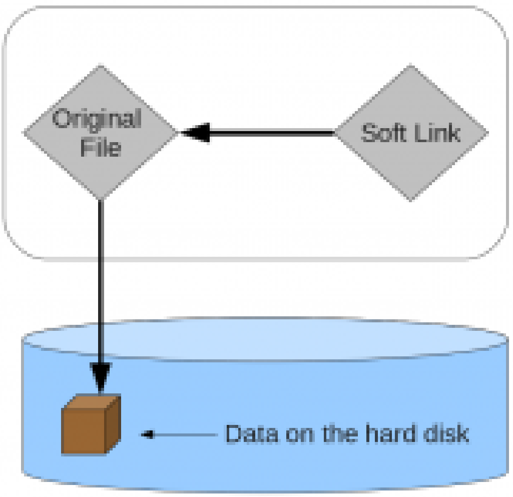
*$ rm /usr/shared/results.log*

# Hard Link Vs Symbolic Link Abstracted View

## Hard Links



## Symbolic Links



**Question: Which type of link is more space efficient ??**

# LINUX COMMANDS

# Creating File Links (ln Command)

- To create a Hard Link

```
$ ln <File to link to> <link name & location>
$ ln file.log   ~/log-files/a.log
```

- To create a Symbolic Link

```
$ ln –s <File to link to> <link name & location>
$ ln -s ~/file.log   ~/log-files/a.log
```

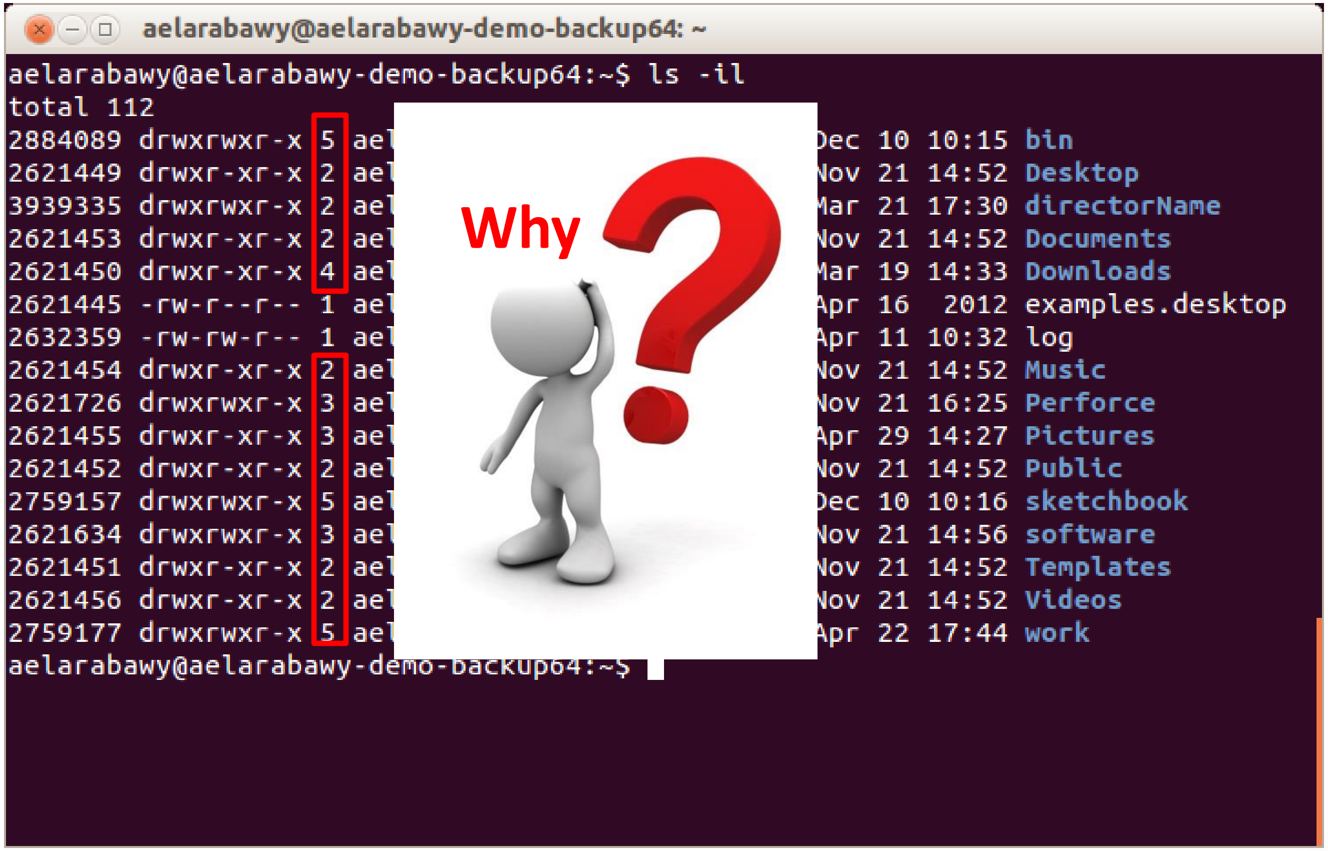
***Important Note:***

***Always use absolute paths for the file to link to when creating symbolic links …. Never use relative path format***

# Question…..

We agreed that Hard links are not allowed for directories…

Now doing a simple listing results in:



```
aelarabawy@aelarabawy-demo-backup64:~$ ls -il
total 112
2884089 drwxrwxr-x 5 ael                          Dec 10 10:15 bin
2621449 drwxr-xr-x 2 ael                          Nov 21 14:52 Desktop
3939335 drwxrwxr-x 2 ael                          Mar 21 17:30 directorName
2621453 drwxr-xr-x 2 ael                          Nov 21 14:52 Documents
2621450 drwxr-xr-x 4 ael                          Mar 19 14:33 Downloads
2621445 -rw-r--r-- 1 ael                          Apr 16  2012 examples.desktop
2632359 -rw-rw-r-- 1 ael                          Apr 11 10:32 log
2621454 drwxr-xr-x 2 ael                          Nov 21 14:52 Music
2621726 drwxrwxr-x 3 ael                          Nov 21 16:25 Perforce
2621455 drwxr-xr-x 3 ael                          Apr 29 14:27 Pictures
2621452 drwxr-xr-x 2 ael                          Nov 21 14:52 Public
2759157 drwxrwxr-x 5 ael                          Dec 10 10:16 sketchbook
2621634 drwxrwxr-x 3 ael                          Nov 21 14:56 software
2621451 drwxr-xr-x 2 ael                          Nov 21 14:52 Templates
2621456 drwxr-xr-x 2 ael                          Nov 21 14:52 Videos
2759177 drwxrwxr-x 5 ael                          Apr 22 17:44 work
aelarabawy@aelarabawy-demo-backup64:~$
```

# Linux4

## Embedded Systems

http://Linux4EmbeddedSystems.com