Operating Systems
Constructor University
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Module: CO-562
Date: 2025-11-21
Due: 2025-11-28

Problem Sheet #12

Problem 12.1: *file system permissions* (1+1 = 2 points)

Unix file system objects have basic permissions associated with (i) the file owner, (ii) the file's group members, and (iii) everybody else with access to the file system.

a) Explain the meaning of the following file access permissions.

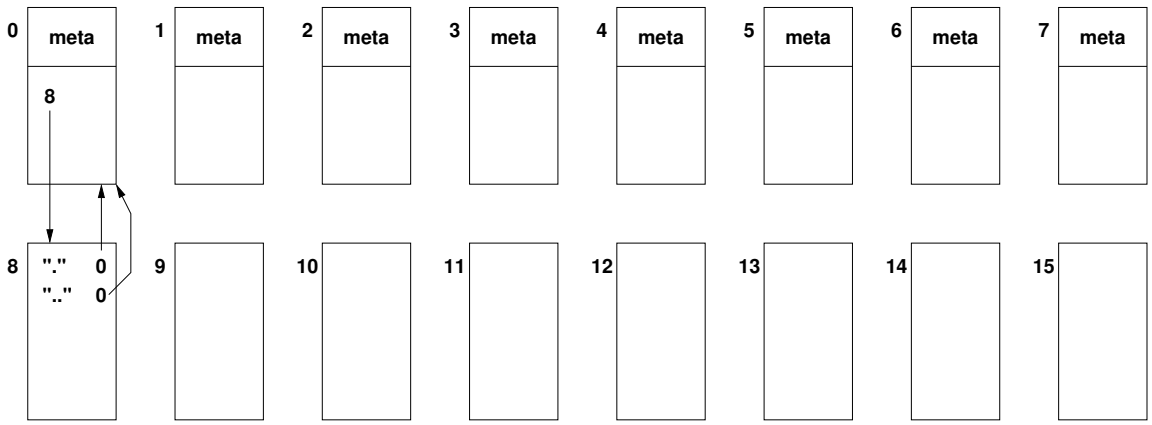
```
$ ls -l /usr/bin/sudo
-rwsr-xr-x  1 root root 294384 Jun 25 12:09 /usr/bin/sudo
$ ls -ld /tmp
drwxrwxrwt 14 root root 320 Nov 20 10:36 /tmp
$ ls -ld /var/mail/
drwxrwsr-x  2 root mail 4096 Aug  8 15:45 /var/mail/
```

b) The regular user `bob` (with a umask of 0002) and with the default group `bob` executes the following shell commands. What are the file permissions of the files `foo` and `bar` and who is the owner? Explain.

```
$ rm -f foo bar
$ touch foo
$ sudo ln foo bar
```

Problem 12.2: *file system updates* (3 points)

Consider a small file system residing on a block device with 16 blocks (numbered 0..15). All blocks have the same size. The first 8 blocks (0...7) are reserved for inodes. An inode stores file attributes (metadata) of a file system object as well as references to data blocks. The remaining blocks (8...15) are reserved for storing data or directory information, they are called data blocks, or short dnodes. The root directory is always found in inode 0. Below is a figure visualizing the situation right after initializing the file system.



In the following, we focus on the block references that the file system maintains. The initial situation can be described as follows:

```
inode 0: 8                        // inode 0 refers to dnode(s) 8
inode i: undef                    // inode i has undefined content (i in {1..7})
dnode 8: {(".", 0), ("..", 0)}    // dnode 8 has 2 directory entries (to inode 0)
dnode i: undef                    // dnode i has undefined content (i in {9..15})
```

We are now making a number of changes to the file system. In the following steps, write down (using the notation shown above) which inodes and/or dnodes are updated. In each step, write down only the blocks that actually change. If you need to allocate so far unused inodes or dnodes, choose lower numbered unused inodes or dnodes first.

a) `mkdir /a`

b) `mkdir /a/b`

c) `echo "hello" > /a/b/c`

d) `mv /a/b/c /a`

e) `ln /a/c /a/b/d`

f) `ln -s /a/b/d /e`

Problem 12.3: *logical volume management* (1+1+1+1+1 = 5 points)

On Linux, you can create block storage devices using regular files as the backend storage. This is useful for experimentation and debugging. You will use this to create physical and logical volumes.

You may want to do this exercise on a virtual machine to make sure you avoid any catastrophic results by accidentally mistyping a command.

Creating block devices on top of regular files is accomplished by loop devices. First, you have to load to the loop kernel module:

```
sudo modprobe loop
```

Next, you create 5 storage devices, each having a capacity of $20\,\mathrm{MB}$.

```
for i in $(seq 0 4) ; do
    img=loop$i.img
    dev=/dev/loop$i
    dd if=/dev/zero of=$img bs=1M count=20
    sudo losetup $dev $img
done
```

To list your loop devices, you can use this command:

```
sudo losetup -a
```

To remove all loop devices and the files, you can run this loop:

```
 for i in $(seq 0 4) ; do
    img=loop$i.img
    dev=/dev/loop$i
    sudo losetup -d $dev
    rm $img
done
```

In order to create logical volumes, you need to install the `lvm2` package (if not installed yet). On Debian or Ubuntu systems, the package can be installed by using the following command:

```
sudo apt-get install lvm2
```

You can get an overview over the lvm commands in the `lvm` man page in section 8 of the Unix manual. Every individual lvm command has its own man page in section 8 as well.

Carry out the following experiments and provide the requested information:

a) Create a volume group named `vg0` that consists of the three physical volumes `/dev/loop0`, `/dev/loop1`, and `/dev/loop2`. Document the commands that you have used and show the output of the commands `sudo pvs` and `sudo vgs`. Look at the `PSize`, what do you observe?

b) Within volume group `vg0`, create a logical volume `lv0` with a size of $20\,\mathrm{MB}$. Create a file system in `lv0` and mount it on `/mnt`. Show the output of the commands `sudo lvs`, `sudo pvs`, and `sudo df /mnt`.

c) You need to grow the file system on `lv0` to about $60\,\mathrm{MB}$. What are the commands that you use and why? Show the the output of the commands `sudo lvs`, `sudo pvs`, and `sudo df /mnt`.

d) Create a snapshot logical volume called `lv0s` of `lv0`. Show the output of the commands `sudo pvs` and `sudo lvs`. Write a short message into the file in `/mnt/msg.txt` (assuming `lv0` is still mounted on `/mnt`). Show the output of the command `sudo lvs` again. What has changed and why? Mount the snapshot volume and verify that the file does not exist in the snapshot file system.

e) Remove all logical volumes from `vg0` and make sure all loop devices have been added as physical volumes to `vg0`. Create a RAID 1 logical volume `lv0r1` with the size of 12Mb. Which physical volumes are used to store the data of `lv0r1`? Create a RAID 5 logical volume `lv1r5` using all the remaining free physical extents. Show the output of the command `sudo lvs`. What is the size of `lv1r5` and what is the size of the physical volumes providing storage for `lv1r5`?