Operating Systems
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Module: CO-562
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OS 2020 Problem Sheet #11

Problem 11.1: *redundant arrays of independent disks* (1+1+1+1+1 = 5 points)

You are given n identical storage disks, each disk has a failure probability p. Lets assume disks fail independently from each other.

a) What is the failure probability F_0 of a RAID 0 (striping) configuration of all n disks? Derive a general expression for $F_0(p, n)$.

b) What is the failure probability F_1 of a RAID 1 (mirroring) configuration of all n disks? Derive a general expression for $F_1(p, n)$.

c) A RAID 10 combines a RAID 1 with a RAID 0. Lets assume that n is an even number and that pairs of two disks are put into RAID 1 configurations and the resulting $\frac{n}{2}$ RAID 1 configurations are put into a RAID 0. What is the resulting failure probability $F_{10}(p, n)$?

d) A RAID 01 combines a RAID 0 with a RAID 1. Lets assume that n is an even number and that $\frac{n}{2}$ disks are put into two RAID 0 configurations and the resulting two RAID 0 configurations are put into a RAID 1. What is the resulting failure probability $F_{01}(p, n)$?

e) If you can choose between a RAID 10 and a RAID 01, which configuration do you prefer? Explain.

Problem 11.2: *logical volume management* (1+1+1+1+1 = 5 points)

On Linux, you can create block storage devices that using a regular file 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 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
```

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 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 filesystem on `lv0` to about 60 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`?