Презентация по лабораторной работе №16

Программный RAID

Амина Аджигалиева

04 декабря 2025

Российский университет дружбы народов, Москва, Россия

Цели и задачи работы

Цель работы

Освоить создание, настройку и управление программными RAID-массивами в Linux с использованием утилиты **mdadm**, а также изучить их отказоустойчивость и принципы перестройки массива при сбоях оборудования.

Ход выполнения работы

Подготовка дисков

```
aradzhigalieva@aradzhigalieva:~$ su
Password:
root@aradzhigalieva:/home/aradzhigalieva# fdisk -l | grep /dev/sd
Disk /dev/sda: 1.5 GiB, 1610612736 bytes, 3145728 sectors
/dev/sda1          2048  616447  614400  300M 8e Linux LVM
/dev/sda2        616448 1230847  614400  300M 8e Linux LVM
Disk /dev/sdb: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdc: 1.5 GiB, 1610612736 bytes, 3145728 sectors
/dev/sdc1          2048 1230847 1228800  600M 8e Linux LVM
/dev/sdc2       1230848 2152447  921600  450M 8e Linux LVM
Disk /dev/sde: 40 GiB, 42949672960 bytes, 83886080 sectors
/dev/sde1     2048     4095     2048   1M BIOS boot
/dev/sde2     4096  2101247  2097152   1G Linux extended boot
/dev/sde3  2101248 83884031 81782784  39G Linux LVM
Disk /dev/sdd: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdf: 512 MiB, 536870912 bytes, 1048576 sectors
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 1: Проверка доступных дисков

Создание разделов

```
root@aradzhigalieva:/home/aradzhigalieva# sfdisk /dev/sdd <<EOF
> ;
> EOF
Checking that no-one is using this disk right now ... OK

Disk /dev/sdd: 512 MiB, 536870912 bytes, 1048576 sectors
Disk model: VBOX HARDDISK
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes

>>> Created a new DOS (MBR) disklabel with disk identifier 0x7d8328fc.
/dev/sdd1: Created a new partition 1 of type 'Linux' and of size 511 MiB.
/dev/sdd2: Done.

New situation:
Disklabel type: dos
Disk identifier: 0x7d8328fc

Device     Boot Start     End Sectors  Size Id Type
/dev/sdd1        2048 1048575 1046528  511M 83 Linux

The partition table has been altered.
Calling ioctl() to re-read partition table.
Syncing disks.
root@aradzhigalieva:/home/aradzhigalieva#
```

Настройка типа разделов под RAID

```
root@aradzhigalieva:/home/aradzhigalieva# sfdisk --print-id /dev/sdb 1
sfdisk: print-id is deprecated in favour of --part-type
83
root@aradzhigalieva:/home/aradzhigalieva# sfdisk --print-id /dev/sdd 1
sfdisk: print-id is deprecated in favour of --part-type
83
root@aradzhigalieva:/home/aradzhigalieva# sfdisk --print-id /dev/sdf 1
sfdisk: print-id is deprecated in favour of --part-type
83
root@aradzhigalieva:/home/aradzhigalieva# sfdisk -T | grep -i raid
fd  Linux raid autodetect
root@aradzhigalieva:/home/aradzhigalieva# sfdisk --change-id /dev/sdb 1 fd
sfdisk: change-id is deprecated in favour of --part-type

The partition table has been altered.
Calling ioctl() to re-read partition table.
Syncing disks.
root@aradzhigalieva:/home/aradzhigalieva# sfdisk --change-id /dev/sdd 1 fd
sfdisk: change-id is deprecated in favour of --part-type

The partition table has been altered.
Calling ioctl() to re-read partition table.
Syncing disks.
root@aradzhigalieva:/home/aradzhigalieva# sfdisk --change-id /dev/sdf 1 fd
sfdisk: change-id is deprecated in favour of --part-type

The partition table has been altered.
Calling ioctl() to re-read partition table.
Syncing disks.
root@aradzhigalieva:/home/aradzhigalieva#
```

Итоговое состояние разделов

```
root@aradzhigalieva:/home/aradzhigalieva# sfdisk -l /dev/sdb
Disk /dev/sdb: 512 MiB, 536870912 bytes, 1048576 sectors
Disk model: VBOX HARDDISK
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0x7dc2939e

Device     Boot Start     End Sectors  Size Id Type
/dev/sdb1        2048 1048575 1046528  511M fd Linux raid autodetect
root@aradzhigalieva:/home/aradzhigalieva# sfdisk -l /dev/sdd
Disk /dev/sdd: 512 MiB, 536870912 bytes, 1048576 sectors
Disk model: VBOX HARDDISK
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0x7d8328fc

Device     Boot Start     End Sectors  Size Id Type
/dev/sdd1        2048 1048575 1046528  511M fd Linux raid autodetect
root@aradzhigalieva:/home/aradzhigalieva# sfdisk -l /dev/sdf
Disk /dev/sdf: 512 MiB, 536870912 bytes, 1048576 sectors
Disk model: VBOX HARDDISK
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0x064def32

Device     Boot Start     End Sectors  Size Id Type
/dev/sdf1        2048 1048575 1046528  511M fd Linux raid autodetect
root@aradzhigalieva:/home/aradzhigalieva#
```

Создание RAID 1

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdb1 /dev/sdd1
mdadm: Note: this array has metadata at the start and
    may not be suitable as a boot device.  If you plan to
    store '/boot' on this device please ensure that
    your boot-loader understands md/v1.x metadata, or use
    --metadata=0.90
mdadm: size set to 522240K
Continue creating array [y/N]? y
mdadm: Defaulting to version 1.2 metadata
mdadm: array /dev/md0 started.
root@aradzhigalieva:/home/aradzhigalieva# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdd1[1] sdb1[0]
      522240 blocks super 1.2 [2/2] [UU]

unused devices: <none>
root@aradzhigalieva:/home/aradzhigalieva# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 0 spares. Use mdadm --detail for more detail.
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 5: Создание RAID и проверка состояния

Детальная информация о RAID 1

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:41:44 2025
        Raid Level : raid1
        Array Size : 522240 (510.00 MiB 534.77 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 2
     Total Devices : 2
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:41:47 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 501badbe:f33a5651:e73e8d06:6d3b4798
            Events : 17

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       1       8       49        1      active sync   /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva#
```

Создание ФС и монтирование RAID

```
root@aradzhigalieva:/home/aradzhigalieva# mkfs.ext4 /dev/md0
mke2fs 1.47.1 (20-May-2024)
Creating filesystem with 522240 1k blocks and 130560 inodes
Filesystem UUID: 33da0afe-fdf8-4f8f-ad30-3c7577ce1b72
Superblock backups stored on blocks:
        8193, 24577, 40961, 57345, 73729, 204801, 221185, 401409

Allocating group tables: done
Writing inode tables: done
Creating journal (8192 blocks): done
Writing superblocks and filesystem accounting information: done

root@aradzhigalieva:/home/aradzhigalieva# mkdir /data/raid
root@aradzhigalieva:/home/aradzhigalieva# mount /dev/md0 /data/raid/
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 7: Создание ФС и монтирование

Добавление RAID в /etc/fstab

```
 GNU nano 8.1                                                /etc/fstab

#
# /etc/fstab
# Created by anaconda on Fri Sep  5 07:48:31 2025
#
# Accessible filesystems, by reference, are maintained under '/dev/disk/'.
# See man pages fstab(5), findfs(8), mount(8) and/or blkid(8) for more info.
#
# After editing this file, run 'systemctl daemon-reload' to update systemd
# units generated from this file.
#
UUID=979ff020-2464-4c10-8441-bb10b43fea61 /                       xfs     defaults        0 0
UUID=2de57be3-2ddc-4d5c-a9ee-5384ed3b992f /boot                   xfs     defaults        0 0
UUID=37baf132-ff2d-40d2-8971-0a34fda074d8 none                    swap    defaults        0 0
/dev/vgdata/lvdata                        /mnt/data               ext4    defaults        1 2
/dev/vggroup/lvgroup                      /mnt/groups             xfs     defaults        1 2
/dev/md0                                  /data/raid              ext4    defaults        1 2

#UUID=0d101af8-6094-44d3-bc04-a693a75a14da /mnt/data xfs defaults 1 2
#UUID=567fadc0-365a-483a-bdbc-c58a907e370b /mnt/data-ext ext4 defaults 1 2
#UUID=6b3e562c-2d15-4528-b304-8c8a391e775b none swap defaults 0 0
```

Рис. 8: Конфигурация fstab

Восстановление массива после сбоя

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# mdadm /dev/md0 --fail /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva# mdadm /dev/md0 --remove /dev/sdd1
mdadm: hot removed /dev/sdd1 from /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm /dev/md0 --add /dev/sdf1
mdadm: added /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:41:44 2025
        Raid Level : raid1
        Array Size : 522240 (510.00 MiB 534.77 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 2
     Total Devices : 2
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:46:08 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 501badbe:f33a5651:e73e8d06:6d3b4798
            Events : 39

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       2       8       81        1      active sync   /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Удаление массива и очистка суперблоков

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# umount /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm --stop /dev/md0
mdadm: stopped /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdb1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 10: Очистка суперблоков

Создание RAID 1 и добавление hotspare

```
root@aradzhigalieva:/home/aradzhigalieva# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdb1 /dev/sdd1
mdadm: Note: this array has metadata at the start and
    may not be suitable as a boot device.  If you plan to
    store '/boot' on this device please ensure that
    your boot-loader understands md/v1.x metadata, or use
    --metadata=0.90
mdadm: size set to 522240K
Continue creating array [y/N]? y
mdadm: Defaulting to version 1.2 metadata
mdadm: array /dev/md0 started.
root@aradzhigalieva:/home/aradzhigalieva# mdadm --add /dev/md0 /dev/sf1
mdadm: stat failed for /dev/sf1: No such file or directory
root@aradzhigalieva:/home/aradzhigalieva# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@aradzhigalieva:/home/aradzhigalieva# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdf1[2](S) sdd1[1] sdb1[0]
      522240 blocks super 1.2 [2/2] [UU]

unused devices: <none>
root@aradzhigalieva:/home/aradzhigalieva# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 11: Создание RAID 1

Проверка состояния массива с hotspare

```
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:49:24 2025
        Raid Level : raid1
        Array Size : 522240 (510.00 MiB 534.77 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 2
     Total Devices : 3
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:49:49 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 6839131f:7e92e0a2:afef2410:8f33fb6f
            Events : 18

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       1       8       49        1      active sync   /dev/sdd1

       2       8       81        -      spare   /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Сбой диска и автоматическая перестройка

```
root@aradzhigalieva:/home/aradzhigalieva# mdadm /dev/md0 --fail /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:49:24 2025
        Raid Level : raid1
        Array Size : 522240 (510.00 MiB 534.77 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 2
     Total Devices : 3
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:52:06 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 1
     Spare Devices : 0

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 6839131f:7e92e0a2:afef2410:8f33fb6f
            Events : 37

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       2       8       81        1      active sync   /dev/sdf1

       1       8       49        -      faulty   /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva#
```

Очистка суперблоков

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# umount /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm --stop /dev/md0
mdadm: stopped /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdb1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 14: Удаление массива и очистка суперблоков

Создание RAID 1

```
root@aradzhigalieva:/home/aradzhigalieva# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdb1 /dev/sdd1
mdadm: Note: this array has metadata at the start and
    may not be suitable as a boot device.  If you plan to
    store '/boot' on this device please ensure that
    your boot-loader understands md/v1.x metadata, or use
    --metadata=0.90
mdadm: size set to 522240K
Continue creating array [y/N]? y
mdadm: Defaulting to version 1.2 metadata
mdadm: array /dev/md0 started.
root@aradzhigalieva:/home/aradzhigalieva# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@aradzhigalieva:/home/aradzhigalieva# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdf1[2](S) sdd1[1] sdb1[0]
      522240 blocks super 1.2 [2/2] [UU]

unused devices: <none>
root@aradzhigalieva:/home/aradzhigalieva# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 15: Создание RAID1

Добавление третьего диска

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:55:14 2025
        Raid Level : raid1
        Array Size : 522240 (510.00 MiB 534.77 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 2
     Total Devices : 3
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:55:33 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 9cc7048a:af92bcf0:61e83946:91f0f679
            Events : 18

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       1       8       49        1      active sync   /dev/sdd1

       2       8       81        -      spare   /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Преобразование RAID 1 → RAID 5

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:55:14 2025
        Raid Level : raid5
        Array Size : 522240 (510.00 MiB 534.77 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 2
     Total Devices : 3
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:56:34 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

            Layout : left-symmetric
        Chunk Size : 64K

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 9cc7048a:af92bcf0:61e83946:91f0f679
            Events : 19

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       1       8       49        1      active sync   /dev/sdd1

       2       8       81        -      spare   /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Расширение RAID 5 до трёх дисков

```
root@aradzhigalieva:/home/aradzhigalieva# mdadm --grow /dev/md0 --raid-devices=3
root@aradzhigalieva:/home/aradzhigalieva# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sat Nov 22 12:55:14 2025
        Raid Level : raid5
        Array Size : 1044480 (1020.00 MiB 1069.55 MB)
     Used Dev Size : 522240 (510.00 MiB 534.77 MB)
      Raid Devices : 3
     Total Devices : 3
       Persistence : Superblock is persistent

       Update Time : Sat Nov 22 12:58:19 2025
             State : clean
    Active Devices : 3
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 0

            Layout : left-symmetric
        Chunk Size : 64K

Consistency Policy : resync

              Name : aradzhigalieva.localdomain:0  (local to host aradzhigalieva.localdomain)
              UUID : 9cc7048a:af92bcf0:61e83946:91f0f679
            Events : 37

    Number   Major   Minor   RaidDevice State
       0       8       17        0      active sync   /dev/sdb1
       1       8       49        1      active sync   /dev/sdd1
       2       8       81        2      active sync   /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Финальная очистка суперблоков

```
root@aradzhigalieva:/home/aradzhigalieva#
root@aradzhigalieva:/home/aradzhigalieva# umount /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm --stop /dev/md0
mdadm: stopped /dev/md0
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdb1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdd1
root@aradzhigalieva:/home/aradzhigalieva# mdadm --zero-superblock /dev/sdf1
root@aradzhigalieva:/home/aradzhigalieva#
```

Рис. 19: Очистка суперблоков

Вывод

Вывод

В ходе лабораторной работы я освоила создание и управление программными RAID-массивами,
на практике изучила уровни RAID 1 и RAID 5, добавление горячего резерва,
а также восстановление и перестройку массива после отказа дисков.

Полученные навыки необходимы для администрирования отказоустойчивых систем хранения данных
и повышения надёжности серверной инфраструктуры.