Лабораторная работа №16

Программный RAID

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Цель работы

Основная цель

Освоить создание, настройку и администрирование программных RAID-массивов с помощью утилиты **mdadm** в Linux.

Ход выполнения работы

Проверка наличия дисков

```
sigamberdov@sigamberdov:~$ su
Password:
root@sigamberdov:/home/sigamberdov#
root@sigamberdov:/home/sigamberdov# fdisk -l | grep /dev/sd
Disk /dev/sda: 40 GiB, 42949672960 bytes, 83886080 sectors
/dev/sda1     2048     4095     2048   1M BIOS boot
/dev/sda2     4096  2101247  2097152   1G Linux extended boot
/dev/sda3  2101248 83884031 81782784  39G Linux LVM
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/sdb: 1.5 GiB, 1610612736 bytes, 3145728 sectors
/dev/sdb1          2048  616447  614400  300M 8e Linux LVM
/dev/sdb2       616448 1230847  614400  300M 8e Linux LVM
Disk /dev/sdd: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sde: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdf: 512 MiB, 536870912 bytes, 1048576 sectors
root@sigamberdov:/home/sigamberdov#
```

Рис. 1: Проверка наличия дисков

Создание разделов

```
root@sigamberdov:/home/sigamberdov# 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 0xa44a1577.
/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: 0xa44a1577

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@sigamberdov:/home/sigamberdov#
```

Проверка типа разделов

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

Изменение типа на RAID autodetect

```
root@sigamberdov:/home/sigamberdov# 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: 0xa44a1577

Device     Boot Start     End Sectors  Size Id Type
/dev/sdd1        2048 1048575 1046528  511M fd Linux raid autodetect
root@sigamberdov:/home/sigamberdov# sfdisk -l /dev/sde
Disk /dev/sde: 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: 0xc54e1efb

Device     Boot Start     End Sectors  Size Id Type
/dev/sde1        2048 1048575 1046528  511M fd Linux raid autodetect
root@sigamberdov:/home/sigamberdov# 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: 0xdc17e364

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

Инициализация массива RAID 1

```
root@sigamberdov:/home/sigamberdov#
root@sigamberdov:/home/sigamberdov# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /
dev/sde1
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@sigamberdov:/home/sigamberdov# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 5: Создание RAID-массива

Состояние массива RAID 1

```
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:30:16 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 : Thu Nov 20 09:30:19 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : 81f23eab:eedfbc88:4887724d:4c49968c
            Events : 17

    Number   Major   Minor   RaidDevice State
       0       8       49        0      active sync   /dev/sdd1
       1       8       65        1      active sync   /dev/sde1
root@sigamberdov:/home/sigamberdov#
```

Создание ФС и монтирование

```
root@sigamberdov:/home/sigamberdov# mkfs.ext4 /dev/md0
mke2fs 1.47.1 (20-May-2024)
Creating filesystem with 522240 1k blocks and 130560 inodes
Filesystem UUID: 3ae4c346-afe8-456c-a321-a2492a47c27a
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@sigamberdov:/home/sigamberdov# mkdir /data
mkdir: cannot create directory ‘/data’: File exists
root@sigamberdov:/home/sigamberdov# mkdir /mnt/raid
root@sigamberdov:/home/sigamberdov# mount /dev/md0 /mnt/raid/
root@sigamberdov:/home/sigamberdov#
```

Рис. 7: Создание ФС и монтирование

Настройка автомонтирования

```
 GNU nano 8.1                                  /etc/fstab

#
# /etc/fstab
# Created by anaconda on Wed Sep 17 09:57:58 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=56362b30-55f8-4f4b-9a9b-2544717501fa /                       xfs     defaults        0 0
UUID=eeeec4be-5545-4b77-be3e-c9b195fe2286 /boot                   xfs     defaults        0 0
UUID=fc4eddc6-c4f4-4723-8f5d-faafa4784cda 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                                  /mnt/raid               ext4    defaults        1 2

#UUID=64b7dd76-1cc8-4235-8ad8-4f90d12c9605 /mnt/data              xfs     defaults        1 2
#UUID=a6678ce7-9195-4c69-89af-3fc1c3aab6a9 /mnt/data-ext                  ext4    defaults        1 2
#UUID=dd15f474-b25a-4385-8bbe-a1ad82ed2852 none                   swap    defaults        0 0
```

Рис. 8: fstab настройка

Симуляция сбойного диска

```
root@sigamberdov:/home/sigamberdov#
root@sigamberdov:/home/sigamberdov# mdadm /dev/md0 --fail /dev/sde1
root@sigamberdov:/home/sigamberdov# mdadm /dev/md0 --remove /dev/sde1
mdadm: hot removed /dev/sde1 from /dev/md0
root@sigamberdov:/home/sigamberdov# mdadm /dev/md0 --add /dev/sdf1
mdadm: added /dev/sdf1
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:30:16 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 : Thu Nov 20 09:33:31 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : 81f23eab:eedfbc88:4887724d:4c49968c
            Events : 39

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

Очистка и остановка массива

```
root@sigamberdov:/home/sigamberdov#
root@sigamberdov:/home/sigamberdov# umount /dev/md0
root@sigamberdov:/home/sigamberdov# mdadm --stop /dev/md0
mdadm: stopped /dev/md0
root@sigamberdov:/home/sigamberdov# mdadm --zero-superblock /dev/sdd1
root@sigamberdov:/home/sigamberdov# mdadm --zero-superblock /dev/sde1
root@sigamberdov:/home/sigamberdov# mdadm --zero-superblock /dev/sdf1
root@sigamberdov:/home/sigamberdov#
```

Рис. 10: Удаление массива

Создание массива и добавление hotspare

```
root@sigamberdov:/home/sigamberdov# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /
dev/sde1
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@sigamberdov:/home/sigamberdov# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@sigamberdov:/home/sigamberdov# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@sigamberdov:/home/sigamberdov# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdf1[2](S) sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 11: Добавление hotspare

Состояние массива с hotspare

```
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:36:45 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 : Thu Nov 20 09:37:09 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : 9d03567e:df9c2d02:3e0b07c3:0b6f1fd1
            Events : 18

    Number   Major   Minor   RaidDevice State
       0       8       49        0      active sync   /dev/sdd1
       1       8       65        1      active sync   /dev/sde1

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

Автоматическое замещение при отказе

```
root@sigamberdov:/home/sigamberdov# mdadm /dev/md0 --fail /dev/sde1
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:36:45 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 : Thu Nov 20 09:38:31 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 1
     Spare Devices : 0

Consistency Policy : resync

              Name : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : 9d03567e:df9c2d02:3e0b07c3:0b6f1fd1
            Events : 37

    Number   Major   Minor   RaidDevice State
       0       8       49        0      active sync   /dev/sdd1
       2       8       81        1      active sync   /dev/sdf1

       1       8       65        -      faulty   /dev/sde1
root@sigamberdov:/home/sigamberdov#
```

Очистка массива

```
root@sigamberdov:/home/sigamberdov#
root@sigamberdov:/home/sigamberdov# umount /dev/md0
root@sigamberdov:/home/sigamberdov# mdadm --stop /dev/md0
mdadm: stopped /dev/md0
root@sigamberdov:/home/sigamberdov# mdadm --zero-superblock /dev/sdd1
root@sigamberdov:/home/sigamberdov# mdadm --zero-superblock /dev/sde1
root@sigamberdov:/home/sigamberdov# mdadm --zero-superblock /dev/sdf1
root@sigamberdov:/home/sigamberdov#
```

Рис. 14: Очистка RAID

Исходный RAID 1

```
root@sigamberdov:/home/sigamberdov# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /
dev/sde1
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@sigamberdov:/home/sigamberdov# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@sigamberdov:/home/sigamberdov# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@sigamberdov:/home/sigamberdov# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdf1[2](S) sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 15: Создание RAID1 вновь

Состояние перед преобразованием

```
root@sigamberdov:/home/sigamberdov#
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:41:41 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 : Thu Nov 20 09:41:59 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : a3012138:4367c39f:ea9270fe:da54e920
            Events : 18

    Number   Major   Minor   RaidDevice State
       0       8       49        0      active sync   /dev/sdd1
       1       8       65        1      active sync   /dev/sde1

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

Изменение уровня массива до RAID 5

```
root@sigamberdov:/home/sigamberdov# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:41:41 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 : Thu Nov 20 09:43:01 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 : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : a3012138:4367c39f:ea9270fe:da54e920
            Events : 19

    Number   Major   Minor   RaidDevice State
       0       8       49        0      active sync   /dev/sdd1
       1       8       65        1      active sync   /dev/sde1

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

Увеличение количества устройств

```
root@sigamberdov:/home/sigamberdov# mdadm --grow /dev/md0 --raid-devices=3
root@sigamberdov:/home/sigamberdov# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Thu Nov 20 09:41:41 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 : Thu Nov 20 09:43:44 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 : sigamberdov.localdomain:0  (local to host sigamberdov.localdomain)
              UUID : a3012138:4367c39f:ea9270fe:da54e920
            Events : 37

    Number   Major   Minor   RaidDevice State
       0       8       49        0      active sync   /dev/sdd1
       1       8       65        1      active sync   /dev/sde1
       2       8       81        2      active sync   /dev/sdf1
root@sigamberdov:/home/sigamberdov#
```

Выводы

Итоги работы

В рамках лабораторной работы были изучены:

- принципы работы программных RAID-массивов;
- создание RAID 1 и RAID 5 при помощи утилиты mdadm;
- работа с горячим резервом (hot spare);
- симуляция отказов и восстановление работоспособности массива;
- преобразование RAID 1 в RAID 5 без потери данных.

Полученные навыки позволяют эффективно администрировать дисковые подсистемы Linux и обеспечивать отказоустойчивость хранения данных.