Лабораторная работа №16

Программный RAID (mdadm)

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Цель работы

Основная цель

Освоить создание, настройку и управление программными RAID-массивами с использованием утилиты **mdadm**.

Ход выполнения

Проверка дисков

```
mlabsi@mlabsi:~$ su
Password:
root@mlabsi:/home/mlabsi# fdisk -l | grep /dev/sd
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/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/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@mlabsi:/home/mlabsi# 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 0x3a4ccb3d.
/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: 0x3a4ccb3d

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.
```

Создание разделов и тип RAID

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

Проверка состояния разделов

```
root@mlabsi:/home/mlabsi# 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: 0x3a4ccb3d

Device     Boot Start     End Sectors  Size Id Type
/dev/sdd1        2048 1048575 1046528  511M fd Linux raid autodetect
root@mlabsi:/home/mlabsi# 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: 0x27ffbc6a

Device     Boot Start     End Sectors  Size Id Type
/dev/sde1        2048 1048575 1046528  511M fd Linux raid autodetect
root@mlabsi:/home/mlabsi# 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: 0x8b191fd8

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

Создание RAID 1

```
root@mlabsi:/home/mlabsi#
root@mlabsi:/home/mlabsi# 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@mlabsi:/home/mlabsi# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 4: Создание RAID 1

Просмотр состояния RAID

```
root@mlabsi:/home/mlabsi#
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:24:46 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 : Mon Dec  8 13:24:49 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : b70b890b:f74a01f7:b2efeaa3:f5279cf0
            Events : 17

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

Создание файловой системы и монтирование

```
root@mlabsi:/home/mlabsi# mkfs.ext4 /dev/md0
mke2fs 1.47.1 (20-May-2024)
Creating filesystem with 522240 1k blocks and 130560 inodes
Filesystem UUID: 4ec61284-7c14-4ca7-a1e2-96add9dc1540
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@mlabsi:/home/mlabsi# mkdir /data/raid
mkdir: cannot create directory ‘/data/raid’: No such file or directory
root@mlabsi:/home/mlabsi# mkdir -p /data/raid
root@mlabsi:/home/mlabsi# mount /dev/md0 /data/raid/
root@mlabsi:/home/mlabsi#
```

Рис. 6: Создание файловой системы

Изменение /etc/fstab

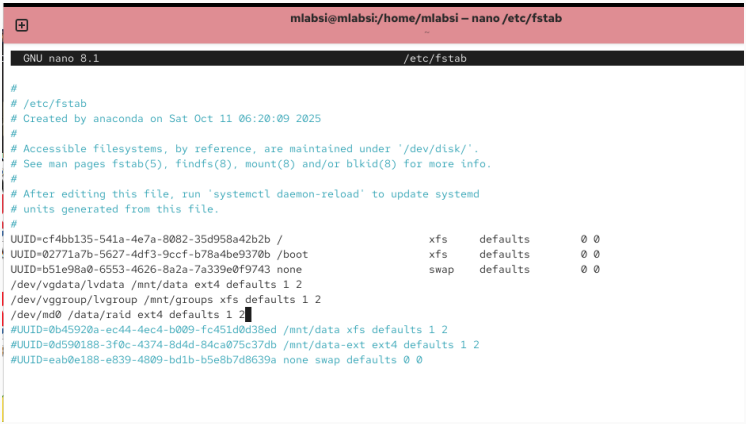

Рис. 7: fstab

Сбой и восстановление диска

Перевод диска в состояние сбоя

```
root@mlabsi:/home/mlabsi#
root@mlabsi:/home/mlabsi# mdadm /dev/md0 --fail /dev/sde1
root@mlabsi:/home/mlabsi# mdadm /dev/md0 --remove /dev/sde1
mdadm: hot removed /dev/sde1 from /dev/md0
root@mlabsi:/home/mlabsi# mdadm /dev/md0 --add /dev/sdf1
mdadm: added /dev/sdf1
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:24:46 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 : Mon Dec  8 13:28:01 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : b70b890b:f74a01f7:b2efeaa3:f5279cf0
            Events : 39

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

Создание массива и добавление hotspare

```
root@mlabsi:/home/mlabsi# 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@mlabsi:/home/mlabsi# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@mlabsi:/home/mlabsi# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@mlabsi:/home/mlabsi# 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@mlabsi:/home/mlabsi# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@mlabsi:/home/mlabsi#
```

Рис. 9: Создание RAID1 с hotspare

Просмотр состояния массива

```
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:31:23 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 : Mon Dec  8 13:31:42 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : fc931632:df56b0aa:baaba8c4:c0fb1c22
            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@mlabsi:/home/mlabsi#
```

Автоматическая активация hotspare после сбоя

```
root@mlabsi:/home/mlabsi# mdadm /dev/md0 --fail /dev/sde1
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:31:23 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 : Mon Dec  8 13:32:56 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 1
     Spare Devices : 0

Consistency Policy : resync

              Name : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : fc931632:df56b0aa:baaba8c4:c0fb1c22
            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@mlabsi:/home/mlabsi#
```

Исходное состояние массива

```
root@mlabsi:/home/mlabsi# 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@mlabsi:/home/mlabsi# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@mlabsi:/home/mlabsi# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@mlabsi:/home/mlabsi# 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@mlabsi:/home/mlabsi# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@mlabsi:/home/mlabsi#
```

Рис. 12: Состояние RAID1 с резервом

Исходное состояние массива

```
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:36:07 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 : Mon Dec  8 13:36:31 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : 23b01db5:1e44866a:2cc93e17:038ac5a6
            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@mlabsi:/home/mlabsi#
```

Преобразование в RAID 5

```
root@mlabsi:/home/mlabsi#
root@mlabsi:/home/mlabsi# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:36:07 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 : Mon Dec  8 13:38:27 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 : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : 23b01db5:1e44866a:2cc93e17:038ac5a6
            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@mlabsi:/home/mlabsi#
```

RAID 5: три активных диска

```
root@mlabsi:/home/mlabsi# mdadm --grow /dev/md0 --raid-devices=3
root@mlabsi:/home/mlabsi# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Dec  8 13:36:07 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 : Mon Dec  8 13:39:01 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 : mlabsi.localdomain:0  (local to host mlabsi.localdomain)
              UUID : 23b01db5:1e44866a:2cc93e17:038ac5a6
            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@mlabsi:/home/mlabsi#
```

Заключение

Заключение

В ходе лабораторной работы были изучены методы конфигурирования программных RAID-массивов, работа с горячим резервом, восстановление после сбоя и преобразование массива между уровнями RAID. Получены практические навыки администрирования отказоустойчивых систем хранения.