Лабораторная работа №16

Программный RAID (mdadm)

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Цель работы

Основная цель

Освоить работу с RAID-массивами при помощи утилиты **mdadm** в Linux.

Создание RAID 1

Проверка дисков

```
raliev@raliev:~$ su
Password:
root@raliev:/home/raliev#
root@raliev:/home/raliev# fdisk -l | grep /dev/sd
Disk /dev/sdd: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdb: 1.5 GiB, 1610612736 bytes, 3145728 sectors
/dev/sdb1          2048 1230847 1228800  600M 8e Linux LVM
/dev/sdb2       1230848 2152447  921600  450M 8e Linux LVM
Disk /dev/sde: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdc: 1.5 GiB, 1610612736 bytes, 3145728 sectors
/dev/sdc1          2048  616447  614400  300M 8e Linux LVM
/dev/sdc2        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/sdf: 512 MiB, 536870912 bytes, 1048576 sectors
root@raliev:/home/raliev#
```

Рис. 1: Проверка дисков /dev/sdd, /dev/sde, /dev/sdf

Создание разделов

```
root@raliev:/home/raliev# 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 0xab842cf4.
/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: 0xab842cf4

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@raliev:/home/raliev#
```

Изменение типа разделов на RAID

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

Состояние дисков

```
root@raliev:/home/raliev#
root@raliev:/home/raliev# 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: 0xab842cf4

Device     Boot Start     End Sectors  Size Id Type
/dev/sdd1        2048 1048575 1046528  511M fd Linux raid autodetect
root@raliev:/home/raliev# 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: 0x9484d887

Device     Boot Start     End Sectors  Size Id Type
/dev/sde1        2048 1048575 1046528  511M fd Linux raid autodetect
root@raliev:/home/raliev# 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: 0x73c354c3

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

Создание RAID 1

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

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

Рис. 5: Создание RAID1

Информация о массиве

```
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 12:49:42 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 : Sun Nov 23 12:49:44 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : fbdd457e:9f66b032:d22d7575:6b354137
            Events : 17

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

Создание файловой системы

```
root@raliev:/home/raliev#
root@raliev:/home/raliev# mkfs.ext4 /dev/md0
mke2fs 1.47.1 (20-May-2024)
Creating filesystem with 522240 1k blocks and 130560 inodes
Filesystem UUID: 08ab9543-70da-4253-9b74-8aec9871c853
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@raliev:/home/raliev# mkdir /mnt/raid
root@raliev:/home/raliev# mount /dev/md0 /mnt/raid
root@raliev:/home/raliev#
```

Рис. 7: Создание файловой системы ext4

Монтирование RAID

```
 GNU nano 8.1                                                /etc/fstab

#
# /etc/fstab
# Created by anaconda on Thu Oct  2 15:51:49 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=3cfbe4aa-6099-4ffb-94d9-9225442b08ab /                       xfs     defaults        0 0
UUID=7b8a1d93-2813-4d48-8617-3be8699122aa /boot                   xfs     defaults        0 0
UUID=43296ceb-b959-4fcf-8f70-625d0f6dfe00 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=7b8716b8-fa43-4c11-ade0-57f582ca8728 /mnt/data              xfs     defaults        1 2
#UUID=9c32754f-0ff7-41f4-83d0-4c6844797287 /mnt/data-ext                  ext4    defaults        1 2
#UUID=f1346f70-6f29-4ebd-83b6-f6e927ec3b4e none                    swap    defaults        1 2
```

Рис. 8: fstab и монтирование

Сбой и замена диска

```
root@raliev:/home/raliev# mdadm /dev/md0 --fail /dev/sde1
root@raliev:/home/raliev# mdadm /dev/md0 --remove /dev/sde1
mdadm: hot removed /dev/sde1 from /dev/md0
root@raliev:/home/raliev# mdadm /dev/md0 --add /dev/sdf1
mdadm: added /dev/sdf1
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 12:49:42 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 : Sun Nov 23 12:53:43 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : fbdd457e:9f66b032:d22d7575:6b354137
            Events : 39

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

RAID 1 с диском горячего резерва

Создание массива RAID1

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

Рис. 10: Создание RAID1

Добавление hot spare

```
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 12:57:54 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 : Sun Nov 23 12:58:15 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : 76d29671:f241305d:3079468e:90265086
            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@raliev:/home/raliev#
```

Сбой диска

```
root@raliev:/home/raliev#
root@raliev:/home/raliev# mdadm /dev/md0 --fail /dev/sde1
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 12:57:54 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 : Sun Nov 23 13:00:35 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 1
     Spare Devices : 0

Consistency Policy : resync

              Name : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : 76d29671:f241305d:3079468e:90265086
            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@raliev:/home/raliev#
```

Преобразование RAID1 → RAID5

RAID1 перед конверсией

```
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 13:02:51 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 : Sun Nov 23 13:03:23 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : 43bf3c49:57bb6a87:3b2ed8d6:e1777793
            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@raliev:/home/raliev#
```

Переход к RAID5

```
root@raliev:/home/raliev# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 13:02:51 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 : Sun Nov 23 13:05:10 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 : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : 43bf3c49:57bb6a87:3b2ed8d6:e1777793
            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@raliev:/home/raliev#
```

RAID5 с двумя активными дисками

```
root@raliev:/home/raliev# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 13:02:51 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 : Sun Nov 23 13:05:10 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 : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : 43bf3c49:57bb6a87:3b2ed8d6:e1777793
            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@raliev:/home/raliev#
```

Добавление третьего диска

```
root@raliev:/home/raliev# mdadm --grow /dev/md0 --raid-devices=3
root@raliev:/home/raliev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Sun Nov 23 13:02:51 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 : Sun Nov 23 13:05:36 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 : raliev.localdomain:0  (local to host raliev.localdomain)
              UUID : 43bf3c49:57bb6a87:3b2ed8d6:e1777793
            Events : 36

    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@raliev:/home/raliev#
```

Заключение

Основной вывод

Изучены методы создания, контроля и преобразования программных RAID-массивов средствами mdadm, включая работу с зеркалированием, горячим резервом и переходом на RAID5. Получены практические навыки настройки отказоустойчивых хранилищ.