

Лабораторная работа №16

Программный RAID

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Цель работы

Формулировка цели

Освоить принципы работы программных RAID-массивов в Linux и получить практические навыки их создания, настройки и администрирования с использованием утилиты `mdadm`.

Ход выполнения работы

Создание RAID 1: подготовка дисков

Проверка наличия подключённых дисков и подготовка их к использованию в RAID-массиве.

```
ivschemelev@ivschemelev:~$ su
Password:
root@ivschemelev:/home/ivschemelev#
root@ivschemelev:/home/ivschemelev# fdisk -l | grep /dev/sd
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/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/sdd: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdc: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sde: 512 MiB, 536870912 bytes, 1048576 sectors
Disk /dev/sdf: 50 GiB, 53687091200 bytes, 104857600 sectors
/dev/sdf1    2048      4095     2048   1M BIOS boot
/dev/sdf2    4096 2101247 2097152   1G Linux extended boot
/dev/sdf3 2101248 104855551 102754304  49G Linux LVM
root@ivschemelev:/home/ivschemelev#
```

Создание разделов на дисках

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

Disk /dev/sdc: 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 0x6d0b2ca3.
/dev/sdcl: Created a new partition 1 of type 'Linux' and of size 511 MiB.
/dev/sdc2: Done.

New situation:
Disklabel type: dos
Disk identifier: 0x6d0b2ca3

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

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

Настройка типа разделов

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

Проверка состояния дисков

```
root@ivschemelev:/home/ivschemelev# 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: 0x9e70955a

Device      Boot Start     End Sectors  Size Id Type
/dev/sdd1          2048 1046528   511M fd Linux raid autodetect
root@ivschemelev:/home/ivschemelev# 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: 0xe9cb286d

Device      Boot Start     End Sectors  Size Id Type
/dev/sde1          2048 1046528   511M fd Linux raid autodetect
root@ivschemelev:/home/ivschemelev# sfdisk -l /dev/sdc
Disk /dev/sdc: 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: 0x6d0b2ca3

Device      Boot Start     End Sectors  Size Id Type
/dev/sdc1          2048 1046528   511M fd Linux raid autodetect
root@ivschemelev#
```

Создание RAID 1

```
root@ivschemelev:/home/ivschemelev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /dev/sde1
To optimalize recovery speed, it is recommended to enable write-indent bitmap, do you want to enable it now? [y/N]?
mdadm: assuming no.
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@ivschemelev:/home/ivschemelev# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 5: Создание RAID 1

Проверка параметров RAID 1

```
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
      Version : 1.2
      Creation Time : Sat Jan 17 14:01:57 2026
      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 Jan 17 14:01:59 2026
      State : clean
      Active Devices : 2
      Working Devices : 2
      Failed Devices : 0
      Spare Devices : 0

      Consistency Policy : resync

              Name : ivschemelev.localdomain:0  (local to host ivschemelev.localdomain)
              UUID : bfae9416:9ca2c450:7d26356d:013112d7
              Events : 17

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

root@ivschemelev:/home/ivschemelev#
```

Файловая система и монтирование

```
GNU nano 8.1                               /etc/fstab

#
# /etc/fstab
# Created by anaconda on Fri Jan 16 11:32:16 2026
#
# 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=b552a213-cc13-43ac-b518-a1c5c52c8d5e /          xfs    defaults      0 0
UUID=7ac262fa-85bd-4a83-808b-8111bf61c34d /boot      xfs    defaults      0 0
UUID=033ba33a-9b4a-4407-81fd-3c8462b17b78 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 ext4 defaults 1 2
#UUID=dbdd84e0-a5ff-48a5-b476-9ba5eb00e66d /mnt/data xfs defaults 1 2
#UUID=397e2311-797e-4490-b3a9-f703326e0342 /mnt/data-ext ext4 defaults 1 2
#UUID=e95c3a0f-a9bf-44f3-811c-cbd748688f8d none swap defaults 0 0
```

Рис. 7: Настройка автомонтирования

Имитация отказа диска

```
root@ivschemelev:/home/ivschemelev# mount | grep md0
/dev/md0 on /data type ext4 (rw,relatime,seclabel)
root@ivschemelev:/home/ivschemelev# mdadm /dev/md0 --fail /dev/sd1
root@ivschemelev:/home/ivschemelev# mdadm /dev/md0 --remove /dev/sd1
mdadm: hot removed /dev/sd1 from /dev/md0
root@ivschemelev:/home/ivschemelev# mdadm /dev/md0 --add /dev/sd1
mdadm: added /dev/sd1
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
    Version : 1.2
    Creation Time : Sat Jan 17 14:01:57 2026
    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 Jan 17 14:05:38 2026
    State : clean
    Active Devices : 2
    Working Devices : 2
    Failed Devices : 0
    Spare Devices : 0

    Consistency Policy : resync

          Name : ivschemelev.localdomain:0 (local to host ivschemelev.localdomain)
          UUID : bfae9416:9ca2c450:7d26356d:013112d7
          Events : 39

          Number  Major  Minor  RaidDevice State
              0      8      49        0     active sync   /dev/sd1
              2      8      33        1     active sync   /dev/sd1
root@ivschemelev:/home/ivschemelev#
```

Создание RAID 1 с hot spare

```
root@ivschemelev:/home/ivschemelev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /dev/sde1
To optimalize recovery speed, it is recommended to enable write-invert bitmap, do you want to enable it now? [y/N]?
mdadm: assuming no.
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@ivschemelev:/home/ivschemelev# mdadm --add /dev/md0 /dev/sdc1
mdadm: added /dev/sdc1
root@ivschemelev:/home/ivschemelev# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
      the old version; use 'systemctl daemon-reload' to reload.
root@ivschemelev:/home/ivschemelev# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdc1[2](S) sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 9: RAID 1 с hot spare

Проверка состояния массива

```
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
      Version : 1.2
      Creation Time : Sat Jan 17 14:07:58 2026
      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 Jan 17 14:08:29 2026
      State : clean
      Active Devices : 2
      Working Devices : 3
      Failed Devices : 0
      Spare Devices : 1

      Consistency Policy : resync

              Name : ivschemelev.localdomain:0  (local to host ivschemelev.localdomain)
              UUID : ec64a403:c5f71fc3:fcd688b5:e4c110fd
              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      33        -    spare     /dev/sdc1
root@ivschemelev:/home/ivschemelev#
```

Отказ и автоматическая перестройка

```
root@ivschemelev:/home/ivschemelev# mdadm /dev/md0 --fail /dev/sde1
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
      Version : 1.2
      Creation Time : Sat Jan 17 14:07:58 2026
      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 Jan 17 14:09:56 2026
      State : clean
      Active Devices : 2
      Working Devices : 2
      Failed Devices : 1
      Spare Devices : 0

      Consistency Policy : resync

              Name : ivschemelev.localdomain:0 (local to host ivschemelev.localdomain)
              UUID : ec64a403:c5f71fc3:fcd688b5:e4c110fd
              Events : 37

      Number  Major  Minor  RaidDevice State
          0      8      49        0    active sync   /dev/sdd1
          2      8      33        1    active sync   /dev/sdc1

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

Исходное состояние массива

```
root@ivschemelev:/home/ivschemelev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /dev/sde1
To optimalize recovery speed, it is recommended to enable write-indent bitmap, do you want to enable it now? [y/N]?
mdadm: assuming no.
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@ivschemelev:/home/ivschemelev# mdadm --add /dev/md0 /dev/sdc1
mdadm: added /dev/sdc1
root@ivschemelev:/home/ivschemelev# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
      the old version; use 'systemctl daemon-reload' to reload.
root@ivschemelev:/home/ivschemelev# cat /proc/mdstat
Personalities : [raid1]
md0 : active raid1 sdc1[2](S) sde1[1] sdd1[0]
      522240 blocks super 1.2 [2/2] [UU]

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

Рис. 12: RAID 1 перед преобразованием

Проверка состояния перед преобразованием

```
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
      Version : 1.2
      Creation Time : Sat Jan 17 14:11:49 2026
      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 Jan 17 14:12:09 2026
      State : clean
      Active Devices : 2
      Working Devices : 3
      Failed Devices : 0
      Spare Devices : 1

      Consistency Policy : resync

              Name : ivschemelev.localdomain:0 (local to host ivschemelev.localdomain)
              UUID : 304cd325:247cbd0c:bed7440e:44abbb23
              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      33        -     spare    /dev/sdc1

root@ivschemelev:/home/ivschemelev#
```

Изменение уровня RAID

```
root@ivschemelev:/home/ivschemelev# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
        Version : 1.2
        Creation Time : Sat Jan 17 14:11:49 2026
        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 Jan 17 14:13:49 2026
        State : clean
        Active Devices : 2
        Working Devices : 3
        Failed Devices : 0
        Spare Devices : 1

        Layout : left-symmetric
        Chunk Size : 64K

        Consistency Policy : resync

              Name : ivschemelev.localdomain:0 (local to host ivschemelev.localdomain)
              UUID : 304cd325:247cbd0c:bed7440e:44abbb23
              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      33        -    spare     /dev/sdc1
root@ivschemelev:/home/ivschemelev#
```

Расширение массива RAID 5

```
root@ivschemelev:/home/ivschemelev# mdadm --grow /dev/md0 --raid-devices=3
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md
mdadm: cannot open /dev/md: No such file or directory
root@ivschemelev:/home/ivschemelev# mdadm --detail /dev/md0
/dev/md0:
          Version : 1.2
          Creation Time : Sat Jan 17 14:11:49 2026
          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 Jan 17 14:14:27 2026
          State : clean
          Active Devices : 3
          Working Devices : 3
          Failed Devices : 0
          Spare Devices : 0

          Layout : left-symmetric
          Chunk Size : 64K

          Consistency Policy : resync

          Name : ivschemelev.localdomain:0 (local to host ivschemelev.localdomain)
          UUID : 304cd325:247cbd0c:bed7440e:44abbb23
          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      33        2    active sync   /dev/sdcl
root@ivschemelev:/home/ivschemelev#
```

Итоги работы

Заключение

В ходе лабораторной работы были изучены основные режимы программного RAID в Linux. Получены практические навыки создания RAID 1, настройки горячего резерва, преобразования массива в RAID 5 и анализа его состояния, что подтверждает понимание принципов отказоустойчивого хранения данных.