Лабораторная работа №16

Программный RAID

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Цель работы

Основная цель

Освоить создание, управление и диагностику RAID-массивов в Linux с использованием утилиты **mdadm**.

Ход выполнения работы

Проверка дисков и подготовка

```
root@titukaev:/home/titukaev# 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 0xb9ea98c1.
/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: 0xb9ea98c1

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@titukaev:/home/titukaev#
```

Создание разделов под RAID

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

Создание RAID 1

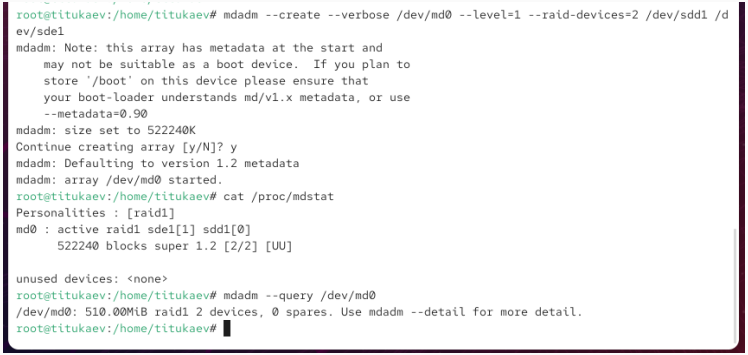

Рис. 3: Создание RAID1

Выполнено создание массива RAID 1 на дисках `/dev/sdd1` и `/dev/sde1`.

Проверка состояния RAID 1

```
root@titukaev:/home/titukaev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Nov 24 11:51:53 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 Nov 24 11:51:55 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 0
     Spare Devices : 0

Consistency Policy : resync

              Name : titukaev.localdomain:0  (local to host titukaev.localdomain)
              UUID : bc085b51:c39ccffb:287ca51d:22045b36
            Events : 17

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

Рис. 4: Состояние RAID1

Монтирование RAID

```
root@titukaev:/home/titukaev# mkfs.ext4 /dev/md0
mke2fs 1.47.1 (20-May-2024)
Creating filesystem with 522240 1k blocks and 130560 inodes
Filesystem UUID: 46302581-4c31-4f28-939c-d1c25e325113
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@titukaev:/home/titukaev# mkdir /mnt/raid
root@titukaev:/home/titukaev# mount /dev/md0 /mnt/raid
root@titukaev:/home/titukaev#
```

Рис. 5: Монтирование RAID

Создана файловая система `ext4`, массив смонтирован в `/mnt/raid`.

Добавление записи в /etc/fstab

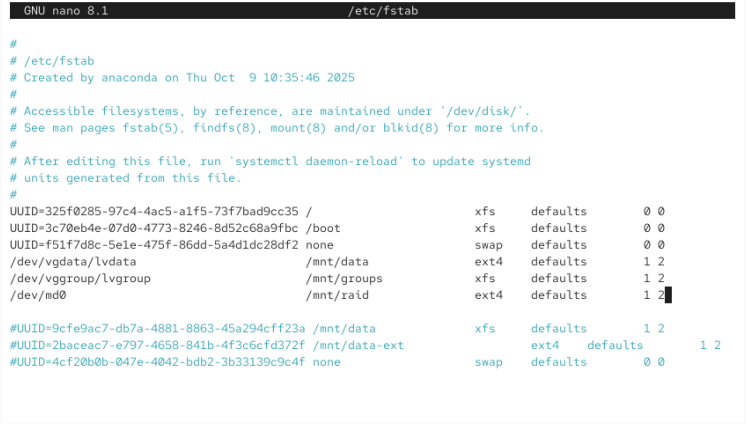

Рис. 6: fstab

Обеспечено автоматическое монтирование RAID при загрузке системы.

RAID с горячим резервом

Добавление hotspare

```
root@titukaev:/home/titukaev#
root@titukaev:/home/titukaev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /d
ev/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@titukaev:/home/titukaev# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@titukaev:/home/titukaev# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@titukaev:/home/titukaev# 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@titukaev:/home/titukaev# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@titukaev:/home/titukaev#
```

Рис. 7: Добавление hotspare

Третий диск `/dev/sdf1` добавлен как **горячий резерв**.

Состояние массива с hotspare

```
root@titukaev:/home/titukaev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Nov 24 11:56:41 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 : Mon Nov 24 11:57:00 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : titukaev.localdomain:0  (local to host titukaev.localdomain)
              UUID : 82cf305a:28e0fe00:193a4484:4f6494d0
            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@titukaev:/home/titukaev#
```

Сбой и автоматическое восстановление

```
root@titukaev:/home/titukaev# mdadm /dev/md0 --fail /dev/sde1
root@titukaev:/home/titukaev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Nov 24 11:56:41 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 : Mon Nov 24 12:00:26 2025
             State : clean
    Active Devices : 2
   Working Devices : 2
    Failed Devices : 1
     Spare Devices : 0

Consistency Policy : resync

              Name : titukaev.localdomain:0  (local to host titukaev.localdomain)
              UUID : 82cf305a:28e0fe00:193a4484:4f6494d0
            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@titukaev:/home/titukaev#
```

Преобразование RAID 1 → RAID 5

Добавление третьего диска

```
root@titukaev:/home/titukaev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /d
ev/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@titukaev:/home/titukaev# mdadm --add /dev/md0 /dev/sdf1
mdadm: added /dev/sdf1
root@titukaev:/home/titukaev# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
       the old version; use 'systemctl daemon-reload' to reload.
root@titukaev:/home/titukaev# 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@titukaev:/home/titukaev# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@titukaev:/home/titukaev#
```

Рис. 10: RAID1 с третьим диском

Базовый RAID 1 дополнен устройством `/dev/sdf1`.

Преобразование в RAID 5

```
root@titukaev:/home/titukaev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Nov 24 12:03:56 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 Nov 24 12:04:14 2025
             State : clean
    Active Devices : 2
   Working Devices : 3
    Failed Devices : 0
     Spare Devices : 1

Consistency Policy : resync

              Name : titukaev.localdomain:0  (local to host titukaev.localdomain)
              UUID : 15903c55:1a68fc19:6b4ef7a2:9c603b94
            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@titukaev:/home/titukaev#
```

Расширение до 3 активных дисков

```
root@titukaev:/home/titukaev# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@titukaev:/home/titukaev# mdadm --detail /dev/md0
/dev/md0:
           Version : 1.2
     Creation Time : Mon Nov 24 12:03:56 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 Nov 24 12:05:09 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 : titukaev.localdomain:0  (local to host titukaev.localdomain)
              UUID : 15903c55:1a68fc19:6b4ef7a2:9c603b94
            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@titukaev:/home/titukaev#
```

Заключение

Выводы

В лабораторной работе освоены:

- создание RAID 1, RAID 5 и массивов с hotspare;
- диагностика состояния массива с помощью `mdadm`;
- обработка отказов и автоматическая реконфигурация массива;
- преобразование RAID без отключения системы.

Получены практические навыки работы с программным RAID в Linux.