

Лабораторная работа №16

Программный RAID

Щемелев Илья Владимирович

Российский университет дружбы народов, Москва, Россия

Цель работы

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#
```

```
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/sdc1: 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/sdc1		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#  
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@ivschemelov:/home/ivschemelov#  
root@ivschemelov:/home/ivschemelov# 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       | 1048575     | 1046528 | 511M | fd Linux raid autodetect |

  
root@ivschemelov:/home/ivschemelov# 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       | 1048575     | 1046528 | 511M | fd Linux raid autodetect |

  
root@ivschemelov:/home/ivschemelov# 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       | 1048575     | 1046528 | 511M | fd Linux raid autodetect |

  
root@ivschemelov:/home/ivschemelov#
```

Создание RAID 1

```
root@ivschemelev:/home/ivschemelev#  
root@ivschemelev:/home/ivschemelev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /dev/sde1  
To optimize 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@ivschemelov:/home/ivschemelov# 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@ivschemelov:/home/ivschemelov#
```

```
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/sde1
root@ivschemelev:/home/ivschemelev# mdadm /dev/md0 --remove /dev/sde1
mdadm: hot removed /dev/sde1 from /dev/md0
root@ivschemelev:/home/ivschemelev# mdadm /dev/md0 --add /dev/sdc1
mdadm: added /dev/sdc1
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/sdd1
       2       8       33        1     active sync  /dev/sdc1
root@ivschemelev:/home/ivschemelev#
```

Создание RAID 1 с hot spare

```
-----,-----,-----
root@ivschemelov:/home/ivschemelov# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /dev/sde1
To optimize 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@ivschemelov:/home/ivschemelov# mdadm --add /dev/md0 /dev/sdc1
mdadm: added /dev/sdc1
root@ivschemelov:/home/ivschemelov# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
the old version; use 'systemctl daemon-reload' to reload.
root@ivschemelov:/home/ivschemelov# 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@ivschemelov:/home/ivschemelov# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@ivschemelov:/home/ivschemelov#
```

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@ivschemev:/home/ivschemev#
root@ivschemev:/home/ivschemev# mdadm --create --verbose /dev/md0 --level=1 --raid-devices=2 /dev/sdd1 /dev/sde1
To optimize 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@ivschemev:/home/ivschemev# mdadm --add /dev/md0 /dev/sdc1
mdadm: added /dev/sdc1
root@ivschemev:/home/ivschemev# mount /dev/md0
mount: (hint) your fstab has been modified, but systemd still uses
the old version; use 'systemctl daemon-reload' to reload.
root@ivschemev:/home/ivschemev# 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@ivschemev:/home/ivschemev# mdadm --query /dev/md0
/dev/md0: 510.00MiB raid1 2 devices, 1 spare. Use mdadm --detail for more detail.
root@ivschemev:/home/ivschemev#
```

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@ivschemellev:/home/ivschemellev# mdadm --grow /dev/md0 --level=5
mdadm: level of /dev/md0 changed to raid5
root@ivschemellev:/home/ivschemellev# 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/sdcl
root@ivschemellev:/home/ivschemellev#
```

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/sdc1

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

Итоги работы

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.