Virtuozzo Storage 2.3

Administrator's Command Line Guide

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Contents

CHAPTER 1

Introduction

This chapter provides basic information about this guide and Virtuozzo Storage.

1.1 About This Guide

This guide complements documentation on managing Virtuozzo Storage via the web-based management panel.

It is recommended to manage Virtuozzo Storage via the management panel. If you have it installed, consider the command-line tools secondary and use them with caution.

If you have the management panel installed, do not do the following via the command-line tools:

- set custom paths for Virtuozzo Storage services, in particular:
  - create S3 clusters only in `/mnt/vstorage/vols/s3`,
  - create iSCSI targets only in `/mnt/vstorage/vols/iscsi`,
- mount clusters or change cluster mount options,
- configure firewall with `firewall-cmd`,
- rename network connections,
- manage MDS/CS,
- manage partitions, LVMs, or software RAID,
- modify files in `/mnt/vstorage/vols` and `/mnt/vstorage/webcp/backup` directories,
- set encoding or replication of cluster root.

1.2 About Virtuozzo Storage

Virtuozzo Storage is a solution allowing you to quickly and easily transform low-cost commodity storage hardware and network equipment into a protected enterprise-level storage, like SAN (Storage Area Network) and NAS (Network Attached Storage).

Virtuozzo Storage is optimized for storing large amounts of data and provides replication, high-availability, and self-healing features for your data. Using Virtuozzo Storage, you can safely store and run virtual machines and Containers, migrate them with zero downtime across physical hosts, provide high availability for your Virtuozzo installations, and much more.

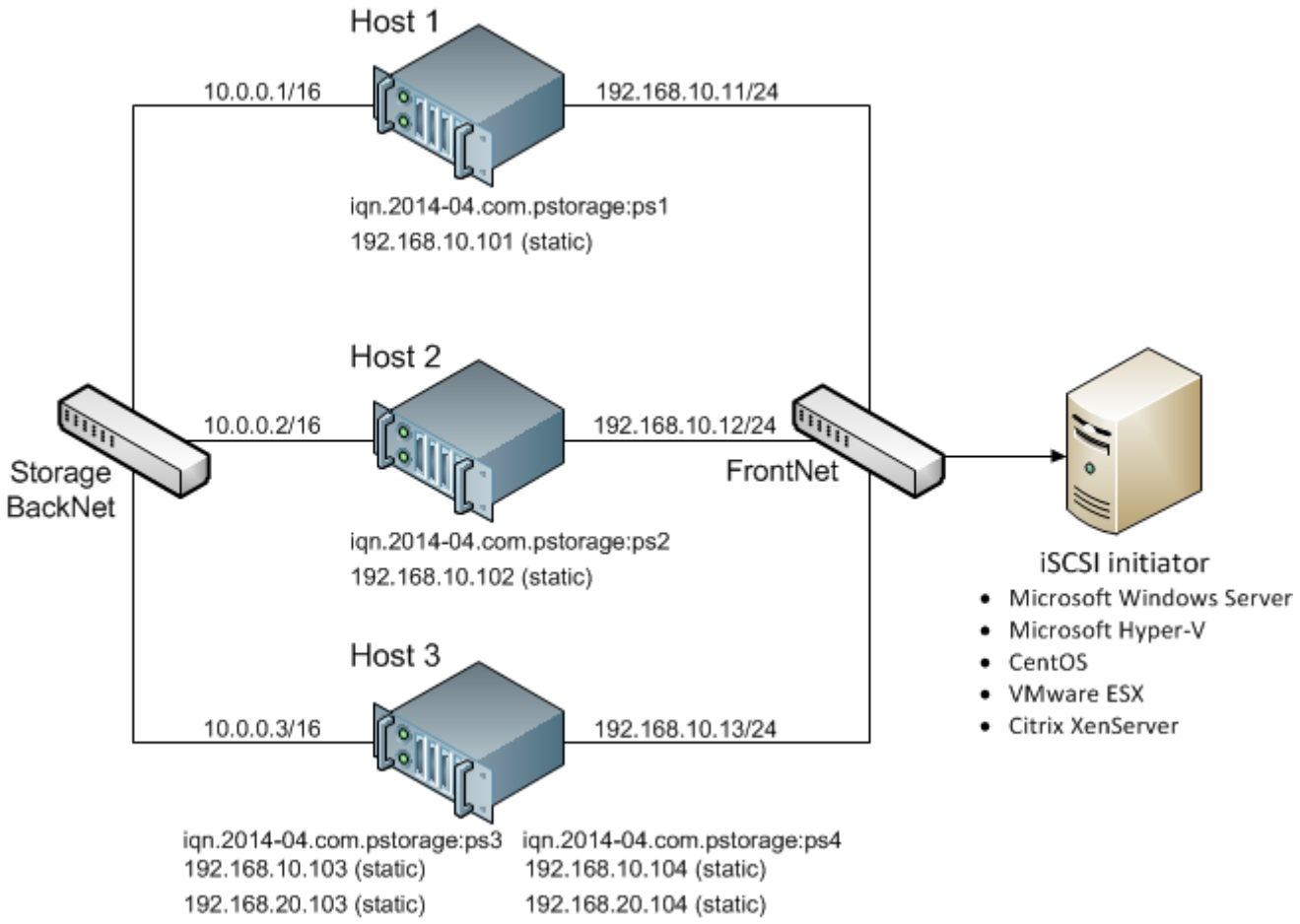
CHAPTER 2

Accessing Virtuozzo Storage Clusters via iSCSI

Virtuozzo Storage allows you to export cluster disk space outside Virtuozzo Storage bounds to operating systems and third-party virtualization solutions. Using dedicated `vstorage-iscsi` tools, you can export Virtuozzo Storage disk space as LUN block devices over iSCSI in a SAN-like manner.

In Virtuozzo Storage, you can create and run multiple iSCSI targets per Virtuozzo Storage cluster node. In turn, each iSCSI target can have multiple LUNs (virtual disks). At any given moment, each iSCSI target runs on a single Hardware node. Thanks to high availability, if a node fails, iSCSI targets hosted on it are moved to and relaunched on a healthy node.

The figure below shows a typical network configured for exporting Virtuozzo Storage disk space over iSCSI.



In this example are three Virtuozzo Hardware nodes working in a Virtuozzo Storage cluster. Two nodes host one iSCSI target each while the third hosts two iSCSI targets. Each node has a static or dynamic IP address assigned from the Storage BackNet (created along with the Virtuozzo Storage cluster) and the FrontNet. Each iSCSI target has a static IP address assigned from the FrontNet.

2.1 Preparing to Work with Virtuozzo Storage iSCSI Targets

On each Virtuozzo Hardware Node, where you need to create and run iSCSI targets, do the following:

1. Make sure the `vstorage-iscsi` and `vstorage-scsi-target-utils` packages are installed on the Hardware Node.
2. Make sure that the Hardware Node has access to the Virtuozzo Storage cluster as client and has an

entry in `/etc/fstab`.

3. Create a directory in the Virtuozzo Storage cluster where you will store iSCSI targets and their configuration. For example, `/vstorage/stor1/iscsi`.
4. Set the `ISCSI_ROOT` variable in `/etc/vstorage/iscsi/config` to the directory from the previous step. For example: ISCSI_ROOT=/vstorage/stor1/iscsi

You are now ready to create and run iSCSI targets in your Virtuozzo Storage cluster.

2.2 Creating and Running Virtuozzo Storage iSCSI Targets

Note:

1. Each iSCSI target must be assigned at least one unique IP address from frontnet's static pool.
2. The name of each iSCSI target must be unique in the Virtuozzo Storage cluster.
3. Virtuozzo Storage iSCSI targets support persistent reservations to allow iSCSI initiators obtain exclusive access to the specified target's LUNs.

To create and start a target `test1` with the size of 100 GB, the LUN of 1, and the IP address of 192.168.10.100, execute the following commands:

```
# vstorage-iscsi create -n test1 -a 192.168.10.100
IQN: iqn.2014-04.com.vstorage:test1
# vstorage-iscsi lun-add -t iqn.2014-04.com.vstorage:test1 -l 1 -s 100G
# vstorage-iscsi start -t iqn.2014-04.com.vstorage:test1
```

Note:

1. If you need to change target's IP address, stop the target as described in *Stopping Virtuozzo Storage iSCSI Targets* on page 8, then run the command `vstorage-iscsi set -t <target_name> -a <new_IP_address>`.
2. If you need to increase the size of a LUN, stop the target as described in *Stopping Virtuozzo Storage iSCSI Targets* on page 8, then run the command `vstorage-iscsi lun-grow -t <target_name> -l <lun_ID> -s <new_size>`.

To check that the target is up, run the `vstorage-iscsi list` command with the target's name as the option. For example:

```
# vstorage-iscsi list -t iqn.2014-04.com.vstorage:test1
Target iqn.2014-04.com.vstorage:test1:
 Portals:     192.168.10.100
 Status:      running
 Registered:  yes
 Host:        fefacc38a2f140ca
 LUN:   1, Size:  102400M, Used:     1M, Online: Yes
```

For information about the command output, see *Listing Virtuozzo Storage iSCSI Targets* on page 6.

iSCSI initiators can now access the target `iqn.2014-04.com.vstorage:test1` via the portal 192.168.10.100.

Performance Tips

- Spread iSCSI targets evenly across Hardware Nodes in the cluster. For example, 10 Hardware Nodes with 1 iSCSI target per each will perform better than a single Hardware Node with 10 iSCSI targets on it.
- More LUNs per fewer iSCSI targets will perform better than fewer LUNs per more iSCSI targets.

2.3 Listing Virtuozzo Storage iSCSI Targets

Using the `vstorage-iscsi list` command, you can list all iSCSI targets registered on a Virtuozzo Storage Node or display detailed information about a specific iSCSI target on a Virtuozzo Storage Node.

To list all iSCSI targets registered on a Virtuozzo Storage Node, run the command as follows:

```
# vstorage-iscsi list
IQN                            STATUS  LUNs HOST             PORTAL(s)
iqn.2014-04.com.vstorage:test1  running 1    fefacc38a2f140ca 192.168.10.100
iqn.2014-04.com.vstorage:test2  running 1    fefacc38a2f140ca 192.168.10.101
iqn.2014-04.com.vstorage:test3  stopped 1    fefacc38a2f140ca 192.168.10.102
iqn.2014-04.com.vstorage:test4  stopped 0    fefacc38a2f140ca 192.168.10.103
```

To display detailed information about an iSCSI target registered on a Virtuozzo Storage Node, run the `vstorage-iscsi list` command with the target's name as the option. For example:

```
# vstorage-iscsi list -t iqn.2014-04.com.vstorage:test1
Target iqn.2014-04.com.vstorage:test1:
 Portals:     192.168.10.100
 Status:      running
 Registered:  yes
```

```
  Host:        fefacc38a2f140ca
  LUN:   1, Size:  102400M, Used:     1M, Online: Yes
```

The command outputs above show the following data:

Item	Description
Target	Unique alphanumeric name of the iSCSI target.
Portals	Target's IP address(es).
Status	Target's current state. • running: target is running and ready for use (for local targets). • stopped: target is stopped (for local targets). • service failed: the iSCSI service is down (for local targets). • remote: target is registered on a different Node. • unregistered: target is not registered on any Node in the Virtuozzo Storage cluster.
Registered	Whether or not the target is registered on the host which ID is shown in the Host entry.
Host	Virtuozzo Storage Hardware Node ID.
LUN	Virtual disk's integer number within the target.
Size	Virtual disk's logical size (16 TB maximum).
Used	Virtual disk's physical size. The physical size can be smaller than logical due to the expanding format of the virtual disk.
Online	• Yes: the LUN is visible to and can be mounted by iSCSI initiators. • No: the LUN is invisible to and cannot be mounted by iSCSI initiators.

2.4 Transferring Virtuozzo Storage iSCSI Targets Between Virtuozzo Storage Nodes

You can transfer stopped iSCSI targets between Virtuozzo Storage Nodes. After the transfer, you will be able to start and manage the iSCSI target on the destination Node. On the source Node, you will only be able to delete the transferred target with the `--force` option (for more details, see *Deleting Virtuozzo Storage iSCSI Targets* on page 8).

To transfer an iSCSI target, do the following:

1. Make sure the target is stopped. For more details, see *Stopping Virtuozzo Storage iSCSI Targets* on page 8.
2. Unregister the target on its current Node with the `vstorage-iscsi unregister` command. For example:

```
# vstorage-iscsi unregister -t iqn.2014-04.com.vstorage:test1
```

3. Register the target on the new Node with the `vstorage-iscsi register` command. For example:

```
# vstorage-iscsi register -t iqn.2014-04.com.vstorage:test1
```

2.5 Stopping Virtuozzo Storage iSCSI Targets

To stop a Virtuozzo Storage iSCSI target to which no initiators are connected, use the `vstorage-iscsi stop` command. For example, for the target `iqn.2014-04.com.vstorage:test1`:

```
# vstorage-iscsi stop -t iqn.2014-04.com.vstorage:test1
```

If one or more iSCSI initiators are still connected to the target, you will be informed as follows:

```
# vstorage-iscsi stop -t iqn.2014-04.com.vstorage:test1
initiators still connected
Initiator:   iqn.1994-05.com.redhat:c678b9f6f0 (192.168.30.100)
Unable stop target iqn.2014-04.com.vstorage:test1
```

In this case, disconnect the iSCSI initiator according to the product manual and run the `vstorage-iscsi stop` command again.

To forcibly stop a target to which one or more initiators are still connected, add the `-f` option to the command above. For example:

```
# vstorage-iscsi stop -t iqn.2014-04.com.vstorage:test1 -f
```

Breaking the iSCSI connection in such a way may result in I/O errors on the iSCSI initiator's side.

2.6 Deleting Virtuozzo Storage iSCSI Targets

You can delete Virtuozzo Storage iSCSI targets with the vstorage-iscsi delete command. Deleting a Virtuozzo Storage iSCSI target, you will also delete all the LUNs within it.

To delete a Virtuozzo Storage iSCSI target, do the following:

1. Make sure the target is stopped (for more details, see *Stopping Virtuozzo Storage iSCSI Targets* on page 8).
2. Run the `vstorage-iscsi delete` command with the target name as the option. For example:

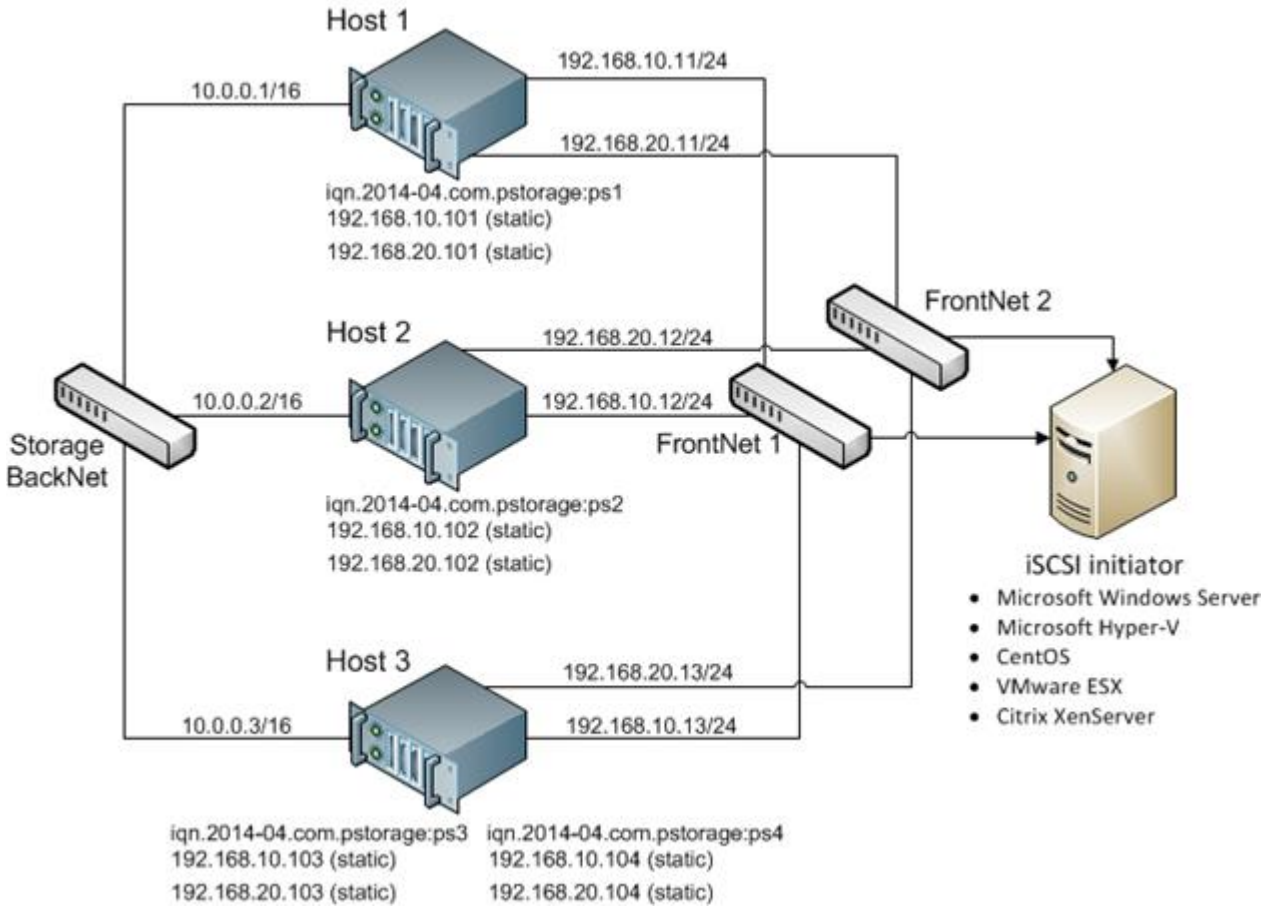
```
# vstorage-iscsi delete -t iqn.2014-04.com.vstorage:test1
```

To delete a stopped iSCSI target registered on a different host, add the `--force` option to the `vstorage-iscsi delete` command. For example:

```
# vstorage-iscsi delete -t iqn.2014-04.com.vstorage:test1 --force
```

2.7 Configuring Multipath I/O for Virtuozzo Storage iSCSI Targets

Multipath I/O is a technique called to increase fault tolerance and performance by establishing multiple paths to the same iSCSI target. The figure below shows a typical multipath-enabled network configured for exporting Virtuozzo Storage disk space over iSCSI.



In this example are three Virtuozzo Hardware Nodes working in a Virtuozzo Storage cluster. Two Nodes host one iSCSI target each while the third hosts two iSCSI targets. Each Hardware Node is assigned a static or dynamic IP address from the FrontNet 1 and the same from the FrontNet 2. In turn, each iSCSI target is assigned a static IP address from the FrontNet 1 and a static IP address from the FrontNet 2. In case one of the frontnets fails, the iSCSI targets will still be accessible via the other one.

To enable multipath I/O for a Virtuozzo Storage iSCSI target, assign to it multiple IP addresses from different networks using the `-a` option. For example, for a Node connected to two networks, 192.168.10.0/24 and 192.168.20.0/24, run the following command:

```
# vstorage-iscsi create -n ps1 -a 192.168.10.101 -a 192.168.20.101
```

2.8 Managing CHAP Accounts for Virtuozzo Storage iSCSI Targets

Virtuozzo Storage allows you to restrict access to iSCSI targets by means of CHAP authentication.

To make use of CHAP authentication, you need to:

1. Create a CHAP account.
2. Create an iSCSI target bound to this CHAP account.

These actions are described in detail in the following subsections.

2.8.1 Creating CHAP Accounts for Virtuozzo Storage iSCSI Targets

To create a CHAP account, use the `vstorage-iscsi account-create` command. For example, to create the CHAP account `user1`:

```
# vstorage-iscsi account-create -u user1
Enter password:
Verify password:
```

2.8.2 Creating Virtuozzo Storage iSCSI Targets Bound to CHAP Accounts

To create a Virtuozzo Storage iSCSI target bound to a CHAP account, use the `vstorage-iscsi create` command with the additional `-u` option. For example, create a target bound to the CHAP account `user1`:

```
# vstorage-iscsi create -n test1 -a 192.168.10.100 -u user1
IQN: iqn.2014-04.com.vstorage:test1
```

2.8.3 Changing the CHAP Account Password

To change the password of a CHAP account, use the `vstorage-iscsi account-set` command. For example, to change the password of the CHAP account `user1`:

```
# vstorage-iscsi account-set -u user1
Enter password:
Verify password:
```

The new password will become active after target reboot.

2.8.4 Listing CHAP Accounts and Virtuozzo Storage iSCSI Targets Assigned to Them

To list existing CHAP accounts, use the `vstorage-iscsi account-list` command. For example:

```
# vstorage-iscsi account-list
user1
```

To list Virtuozzo Storage iSCSI targets assigned to a specific CHAP account, use the `vstorage-iscsi account-list` command with the `-u` option. For example, to list iSCSI targets assigned to the CHAP account `user1`:

```
# vstorage-iscsi account-list -u user1
iqn.2014-04.com.vstorage:test1
```

2.9 Managing LUN Snapshots

As with virtual machines, you can create and manage snapshots of LUNs. At that, to create a snapshot of the entire target, you will need to create snapshots of each LUN within it.

2.9.1 Creating LUN Snapshots

To create a snapshot of a LUN in an iSCSI target, use the `vstorage-iscsi snapshot-create` command. For example, for LUN 1 on target `iqn.2014-04.com.vstorage:test1`:

```
# vstorage-iscsi snapshot-create -t iqn.2014-04.com.vstorage:test1 -l 1
Snapshot a1f54314-bc06-40c6-a587-965feb9d85bb successfully created.
```

Note: To generate a UUID manually, use `uuidgen`.

2.9.2 Listing LUN Snapshots

To list snapshots for the specified LUN, use the `vstorage-iscsi snapshot-list` command. For example, for LUN 1 on `target iqn.2014-04.com.vstorage:test1`:

```
# vstorage-iscsi snapshot-list -t iqn.2014-04.com.vstorage:stor4 -l 1
CREATED             C UUID                                 PARENT_UUID
2014-04-11 13:16:51   a1f54314-bc06-40c6-a587-{...} 00000000-0000-0000-{...}
2014-04-11 13:16:57 * 9c98b442-7482-4fd0-9c45-{...} a1f54314-bc06-40c6-{...}
```

In the output above, the asterisk in the column `C` indicates the current snapshot, while the column `PARENT_UUID` shows snapshot dependency or history.

2.9.3 Switching Between LUN Snapshots

To switch to the specified LUN snapshot, use the `vstorage-iscsi snapshot-switch` command. For example:

```
# vstorage-iscsi snapshot-switch -u a1f54314-bc06-40c6-a587-965feb9d85bb
```

After you switch to a snapshot, the current LUN image will be removed.

Note: You can only switch between snapshots, if the LUN is offline.

2.9.4 Viewing LUN Snapshot Information

To view information about the specified snapshot, use the `vstorage-iscsi snapshot-info` command. For example:

```
# vstorage-iscsi snapshot-info -u 9c98b442-7482-4fd0-9c45-9259374ca84e
Target: iqn.2014-04.com.vstorage:stor4
LUN: 1
Created: 2014-04-11 13:16:57
```

```
Parent: 00000000-0000-0000-0000-000000000000}
{a1f54314-bc06-40c6-a587-965feb9d85bb}
{9c98b442-7482-4fd0-9c45-9259374ca84e
Description: None
```

2.9.5 Deleting LUN Snapshots

To delete the specifed LUN snapshot, use the `vstorage-iscsi snapshot-delete` command. For example:

```
# vstorage-iscsi snapshot-delete -u a1f54314-bc06-40c6-a587-965feb9d85bb
```

If the snapshot has no any children, it will be deleted. If the snapshot has a single child, it will be merged to that child.

Note:

1. You can only delete offline snapshots.
2. Deleting a snapshot that has multiple children is currently not supported.

CHAPTER 3

Accessing Virtuozzo Storage Clusters via S3 Protocol

Virtuozzo Storage can export data via an Amazon S3-compatible API, enabling service providers to:

- run S3-based services in their own Virtuozzo Storage infrastructures,
- sell S3-based storage-as-a-service to customers along with Virtuozzo Storage.

The support for S3 expands the functionality of Virtuozzo Storage and requires a working Virtuozzo Storage cluster.

3.1 About Object Storage

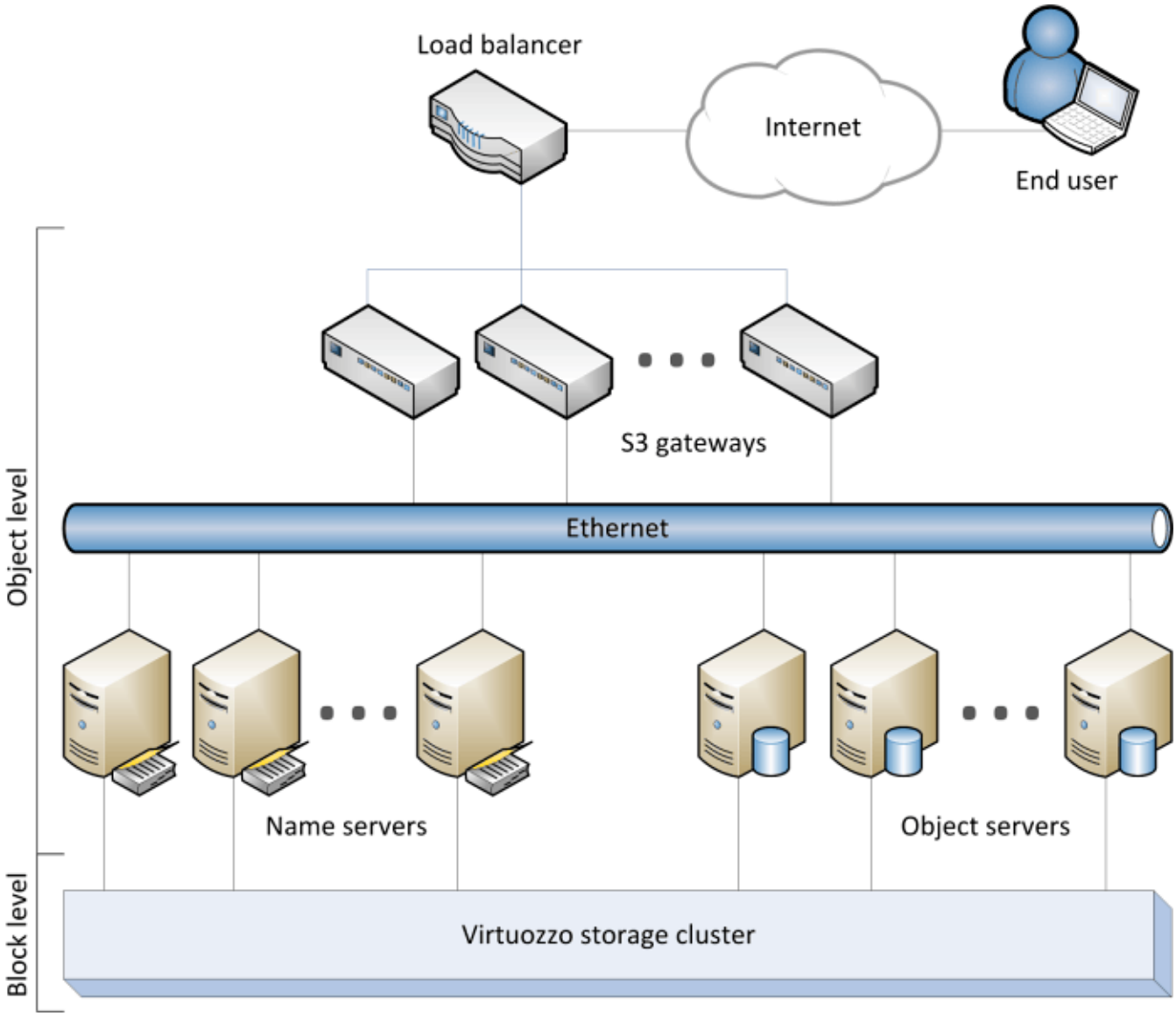
Object storage is a storage architecture that enables managing data as objects (like in key-value storage) as opposed to files in file systems or blocks in block storage. Except data, each object has name (i.e. full path to object) that describes it and also a unique identifier that allows finding said object in the storage. Object storage is optimized for storing billions of objects, in particular for application back-end storage, static web content hosting, online storage services, big data, and backups. All of these uses are enabled by object storage thanks to a combination of very high scalability and data availability and consistency.

Compared to other types of storage, the key difference of S3 object storage is that parts of an object cannot be modified, so if the object changes a new version of it is spawned instead. This approach is extremely important for maintaining data availability and consistency. First of all, changing an object as a whole eliminates the issue of conflicts. That is, the object with the latest timestamp is considered to be the current version and that is it. As a result, objects are always consistent, i.e. their state is relevant and appropriate.

Another feature of object storage is eventual consistency. Eventual consistency does not guarantee that reads are to return the new state after the write has been completed. Readers can observe the old state for an undefined period of time until the write is propagated to all the replicas (copies). This is very important for storage availability as geographically distant data centers may not be able to perform data update synchronously (e.g., due to network issues) and the update itself may also be slow as awaiting acknowledges from all the data replicas over long distances can take hundreds of milliseconds. So eventual consistency helps hide communication latencies on writes at the cost of the probable old state observed by readers. However, many use cases can easily tolerate it.

3.1.1 Object Storage Infrastructure

The infrastructure of Virtuozzo Object Storage consists of the following entities: object servers, name servers, S3 gateways, and the block level backend.



- Object server (OS) stores actual object data (contents) received from S3 gateway. It stores its own data in regular Virtuozzo Storage with built-in high availability.
- Name server stores object metadata received from S3 gateway. Metadata includes object name, size, ACL (access control list), location, owner, and such. Name server (NS) also stores its own data in regular Virtuozzo storage with built-in high availability.
- S3 gateway (GW) is a data proxy between object storage services and end users. It receives and handles Amazon S3 protocol requests and uses `nginx` Web server for external connections. S3 gateway handles S3 user authentication and ACL checks. It has no data of its own (i.e. is stateless).
- Block level backend is regular Virtuozzo storage with high availability of services and data. Since all

object storage services run on hosts, no virtual environments (or respective licenses) are required for object storage.

3.1.2 Object Storage Overview

In terms of S3 object storage, a file is an object. Object servers store each object loaded via the S3 API as a pair of entities:

- Object names and associated object metadata stored on an NS. An object name in the storage is determined based on request parameters and bucket properties in the following way:
  - If bucket versioning is disabled, an object name in the storage contains bucket name and object name taken from an S3 request.
  - If bucket versioning is enabled, an object name also contains a list of object versions.
- Object data stored on an OS. The directory part of an object name determines an NS to store it while the full object name determines an OS to store the object data.

3.1.2.1 Multipart Uploads

A name of a multipart upload is defined by a pattern similar to that of an object name but the object that corresponds to it contains a table instead of file contents. The table contains index numbers of parts and their offsets within the file. This allows to upload parts of a multi-part upload in parallel (recommended for large files). The maximum number of parts is 10,000.

3.1.2.2 S3 Storage Interaction with a Virtuozzo Storage Cluster

An S3 storage cluster requires a working Virtuozzo Storage cluster on each of S3 cluster nodes. Virtuozzo Storage provides content sharing, strong consistency, data availability, reasonable performance for random I/O operations, and high availability for storage services. In storage terms, S3 data is a set of files (see *Object Server* on page 19) that the Virtuozzo Storage file system layer (vstorage-mount) does not interpret in any way.

3.1.3 Object Storage Components

This section familiarises you with S3 storage components—gateways, object servers, and name servers—and describes S3 management tools and service buckets.

3.1.3.1 Gateway

Gateway performs the following functions:

- Receives S3 requests from the web server (via nginx and FastCGI).
- Parses S3 packets and validates S3 requests (checks fields of a request and XML documents in its body).
- Authenticates S3 users.
- Validates access permissions to buckets and objects using ACL.
- Collects statistics on the number of various requests as well as the amount of the data received and transmitted.
- Determines paths to NS and OS storing the object's data.
- Inquires names and associated metadata from NS.
- Receives links to objects stored on OSes by requesting the name from NSes.
- Caches metadata and ACL of S3 objects received from NSes as well as the data necessary for user authentication also stored on the NSes.
- Acts as a proxy server when clients write and read object data to and from the OSes. Only the requested data is transferred during read and write operations. For example, if a user requests to read 10MB from a 1TB object, only said 10MB will be read from the OS.

S3 gateway consists of incoming requests parser, type-dependent asynchronous handlers of these requests, and an asynchronous handler of the interrupted requests that require completion (complex operations such as bucket creation or removal). Gateway does not store its state data in the long-term memory. Instead, it stores all the data needed for S3 storage in the object storage itself (on NS and OS).

3.1.3.2 Name Server

Name server performs the following functions:

- Stores object names and metadata.
- Provides the API for pasting, deleting, listing object names and changing object metadata.

Name server consists of data (i.e. object metadata), object change log, an asynchronous garbage collector, and asynchronous handlers of incoming requests from different system components.

The data is stored in a B-tree where to each object's name corresponds that object's metadata structure. S3 object metadata consists of three parts: information on object, user-defined headers (optional), and ACL for the object. Files are stored in the corresponding directory on base shared storage (i.e. Virtuozzo Storage).

Name server is responsible for a subset of S3 cluster object namespace. Each NS instance is a userspace process that works in parallel with other processes and can utilize up to one CPU core. The optimal number of name servers are 4-10 per node. We recommend to start with creating 10 instances per node during cluster creation to simplify scalability later. If your node has CPU cores that are not utilized by other storage services, you can create more NSes to utilize these CPU cores.

3.1.3.3 Object Server

Object server performs the following functions:

- Stores object data in pools (data containers).
- Provides an API for creating, reading (including partial reads), writing to, and deleting objects.

Object server consists of the following:

- information on object's blocks stored on this OS,
- containers that store object data,
- asynchronous garbage collector that frees container sections after object delete operations.

Object data blocks are stored in pools. The storage uses 12 pools with blocks the size of the power of 2, ranging from 4 kilobytes to 8 megabytes. A pool is a regular file on block storage made of fixed-size blocks (regions). In other words, each pool is an extremely large file designed to hold objects of specific size: the first pool is for 4KB objects, the second pool is for 8KB objects, etc.

Each pool consists of a block with system information, and fixed-size data regions. Each region contains has a free/dirty bit mask. The region's data is stored in the same file with an object's B-tree. It provides atomicity during the block's allocation and deallocation. Every block in the region contains a header and object's data. The header stores the ID of an object to which the data belong. The ID is required for a pool-level defragmentation algorithm that does not have an access to the object's B-tree. A pool to store an object is chosen depending on object size.

For example, a 30KB object will be placed into the pool for 32KB objects and will occupy a single 32KB object. A 129KB object will be split into one 128KB part and one 1KB part. The former will be placed in the pool for 128KB objects while the latter will go to the pool for 4KB objects. The overhead may seem significant in case

of small objects as even a 1-byte object will occupy a 4KB block. In addition, about 4KB of metadata per object will be stored on NS. However, this approach allows achieving the maximum performance, eliminates free space fragmentation, and offers guaranteed object insert performance. Moreover, the larger the object, the less noticeable the overhead. Finally, when an object is deleted, its pool block is marked free and can be used to store new objects.

Multi-part objects are stored as parts (each part being itself an object) that may be stored on different object servers.

3.1.3.4 S3 Management Tools

Object storage has two tools:

- `ostor` for configuring storage components, and
- `s3-ostor-admin` for user management, an application that allows to create, edit, and delete S3 user accounts as well as manage account access keys (create and delete paired S3 access key IDs and S3 secret access keys).

3.1.3.5 Service Bucket

The service bucket stores service and temporary information necessary for the S3 storage. This bucket is only accessible by the S3 admin (while the system admin would need access keys created with the `s3-ostor-admin` tool). The information corresponds to the following names in the object storage:

- Names with a `/u/` prefix. Correspond to user data (user identifier, e-mail, access key ID, and secret access key).
- Names with an `/m/` prefix. Correspond to temporary information on current multipart uploads and their parts.
- Names with a `/tmp/` prefix. Correspond to information on operations that consist of several atomic alterations of objects in the storage. These names are necessary in case the operation fails.

3.1.4 Data Interchange

In Virtuozzo object storage, every service has a 64-bit unique identifier. At the same time, every object has a unique name. The directory part of an object's name determines a name server to store it, and the full

object's name—an object server to store the object's data. Name and object server lists are stored in a `vstorage` cluster directory intended for object storage data and available to anyone with a cluster access. This directory includes subdirectories that correspond to services hosted on name and object servers. The names of subdirectories match hexadecimal representations of the service's ID. In each service's subdirectory, there is a file containing an ID of a host that runs the service. Thus, with the help of a gateway, a system component with a cluster access can discover an ID of a service, detect its host, and send a request to it.

S3 gateway handles data interchange with the following components:

- Clients via a web server. Gateway receives S3 requests from users and responds to them.
- Name servers. Gateway creates, deletes, changes the names that correspond to S3 buckets or objects, checks their existence, and requests name sets of bucket lists.
- Object servers in the storage. Gateway sends data altering requests to object and name servers.

3.1.4.1 Data Caching

To enable efficient data use in object storage, all gateways, name servers, and object servers cache the data they store. Name and object servers both cache B-trees.

Gateways store and cache the following data received from name services:

- Lists of paired user IDs and e-mails.
- Data necessary for user authentication: access key IDs and secret access keys. For more information on their semantics, consult the Amazon S3 documentation.
- Metadata and bucket's ACLs. The metadata contains its epoch, current version identifier and transmits it to NS to check if the gateway has the latest version of the metadata.

3.1.5 Operations on Objects

This section familiarizes you with operations S3 storage processes: operations requests; create, read, and delete operations.

3.1.5.1 Operation Requests

To create, delete, read an object or alter its data, S3 object storage must first request one if these operations and then perform it. The overall process of requesting and performing an operation consists of the following:

1. Requesting user authentication data. It will be stored on a name server in a specific format (see Service Buckets). To receive data (identifier, e-mail, access keys), a request with a lookup operation code is sent to an appropriate name server.
2. Authenticating the user.
3. Requesting bucket's and object's metadata. To receive it, another request with a lookup operation code is sent to the name server that stores names of objects and buckets.
4. Checking user's access permissions to buckets and objects.
5. Performing the requested object operation: creating, editing or reading data or deleting the object.

3.1.5.2 Create Operation

To create an object, gateway sends the following requests:

1. Request with a guard operation code to a name server. It creates a guard with a timer which will check after a fixed time period if an object with the data was indeed created. If it was not, the create operation will fail and the guard will request the object server to delete the object's data if some were written. After that the guard is deleted.
2. Request with a create operation code to an object server followed by fixed-size messages containing the object's data. The last message includes an end-of-data flag.
3. Another request with a create operation code to the name server. The server checks if the corresponding guard exists and, if it does not, the operation fails. Otherwise, the server creates a name and sends a confirmation of successful creation to the gateway.

3.1.5.3 Read Operation

To fulfill an S3 read request, gateway determines an appropriate name server's identifier based on the name of a directory and corresponding object server's identifier based on the object's full name. To perform a read operation, gateway sends the following requests:

1. Request with a read operation code to an appropriate name server. A response to it contains a link to an object.
2. Request to an appropriate object server with a read operation code and a link to an object received from the name server.

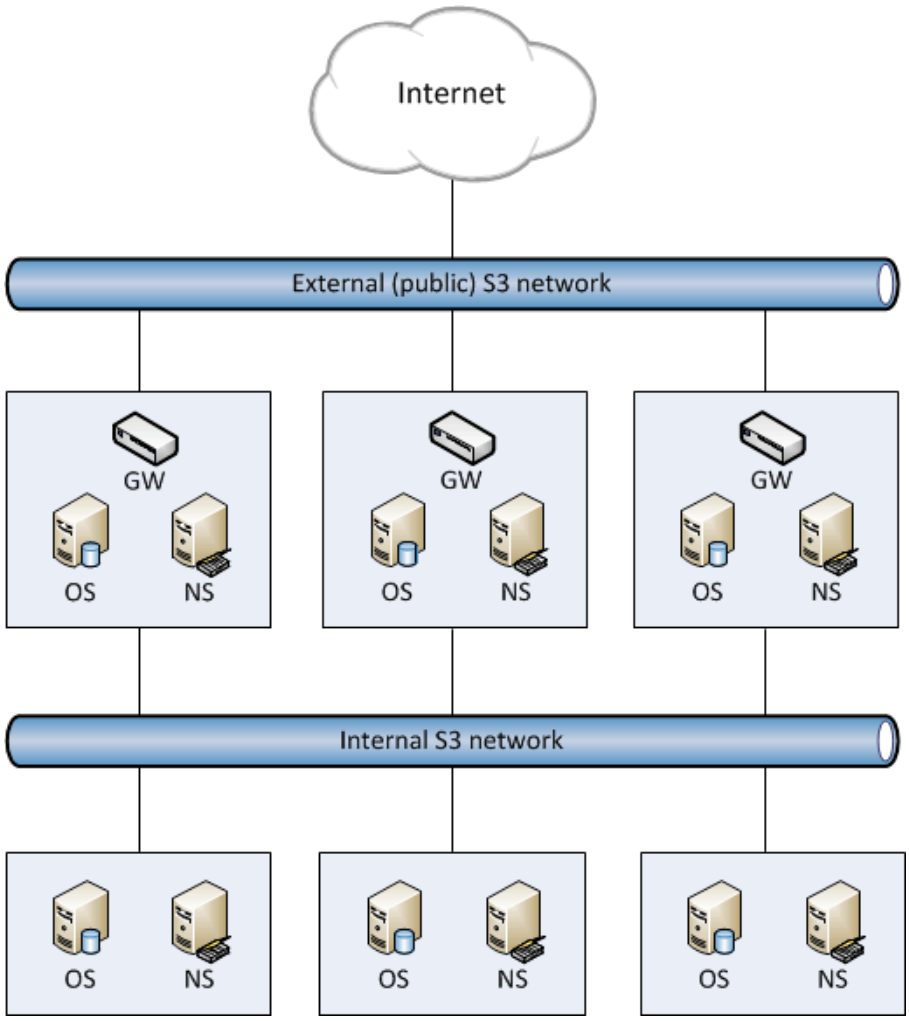
To fulfill the request, object server transmits fixed-size messages with the object's data to the gateway. The last message contains an end-of-data flag.

3.1.5.4 Delete Operation

To delete an object (and its name) from the storage, gateway determines a name server's identifier based on the directory's part of a name and sends a request with a delete operation code to the server. In turn, the name server removes the name from its structures and sends the response. After some time, the garbage collector removes the corresponding object from the storage.

3.2 Deploying Object Storage

This chapter describes deploying object storage on top of a ready Virtuozzo Storage cluster. As a result you will create a setup like shown on the figure. Note that not all cluster nodes have to run object storage services. The choice should be based on workload and hardware configurations.



To set up object storage services, do the following:

1. Plan the S3 network. Like a Virtuozzo Storage cluster, an object storage cluster needs two networks:

   - An internal network in which NS, OS, and GW will interact. These services will generate traffic similar in amount to the total (incoming and outgoing) S3 user traffic. If this is not going to be much, it is reasonable to use the same internal network for both object storage and Virtuozzo Storage. If, however, you expect that object storage traffic will compete with Virtuozzo Storage traffic, it is reasonable to have S3 traffic go through the user data network (i.e. datacenter network). Once you choose a network for S3 traffic, you determine which IP addresses can be used while adding cluster nodes.
   - An external (public) network through which end users will access the S3 storage. Standard HTTP and HTTPS ports must be open in this network.

   An object storage cluster is almost completely independent on base block storage (like all access points,

including virtual environments and iSCSI). Object and name servers keep their data in the Virtuozzo Storage cluster in the same way as virtual environments, iSCSI, and other services do. So the OS and NS services depend on vstorage-mount (client) and can only work when the cluster is mounted. Unlike them, gateway is a stateless service that has no data. It is thus independent on vstorage-mount and can theoretically be run even on nodes where the Virtuozzo Storage cluster is not mounted. However, for simplicity, we recommend creating gateways on nodes with object and name servers.

Object and name servers also utilize the standard high availability means of Virtuozzo Storage (i.e. the shaman service). Like virtual environments and iSCSI, OS and NS are subscribed to HA cluster events. However, unlike other services, S3 cluster components cannot be managed (tracked and relocated between nodes) by shaman. Instead, this is done by the S3 configuration service that is subscribed to HA cluster events and notified by shaman whether nodes are healthy and can run services. For this reason, S3 cluster components are not shown in `shaman top` output.

Gateway services which are stateless are never relocated and their high availability is not managed by the Virtuozzo Storage cluster. Instead, a new gateway service is created when necessary.

2. Make sure that each node that will run OS and NS services is in the high availability cluster. You can add nodes to HA cluster with the `shaman join` command.

3. Install the `vstorage-ostor` package on each cluster node.

```
# yum install vstorage-ostor
```

4. Create a cluster configuration on one of the cluster nodes where object storage services will run. It is recommended to create 10 NS and 10 OS services per each node. For example, if you are going to use five nodes, you will need 50 NS and 50 OS. Run this command on the first cluster node.

```
# ostor-ctl create -n <IP_addr> \
         -c "vstorage://<cluster_name>/<ostor_dir> <NS_num> <OS_num>"
```

where

- `<IP_addr>` is the node's IP address that object storage will go through,
- `<cluster_name>` is the name of your Virtuozzo Storage cluster,
- `<ostor_dir>` is the directory in the cluster with object storage service files,
- `<NS_num>`, `<OS_num>` are the numbers of NS and OS, respectively.

You will be asked to enter and confirm a password for the new object storage (it can be the same as your Virtuozzo Storage cluster password). You will need this password to add new nodes.

5. Launch the configuration service.

```
# systemctl start ostor-cfgd.service
# systemctl enable ostor-cfgd.service
```

6. Initialize new object storage on the first node. The `ostor_dir` directory will be created in the root of your cluster.

```
# ostor-ctl init-storage -n <IP_addr> -s <cluster_mount_point>
```

   You will need to provide the IP address and object storage password specified on step 3.

7. Add to the DNS public IP addresses of nodes that will run GW services. You can configure the DNS to enable access to your object storage via a hostname, and to have the S3 endpoint receive virtual hosted-style REST API requests with URIs like http://bucketname.s3.example.com/objectname.

   After configuring DNS, make sure that DNS resolver for your S3 access point works from client machines.

> **Note:** Only buckets with DNS-compatible names can be accessed with virtual hosted-style requests. For more details, see *Bucket and Key Naming Policies* on page 35.

   Below is an example of a DNS zones configuration file for the BIND DNS server:

```
;$Id$
$TTL 1h  @  IN   SOA    ns.example.com. s3.example.com. (
                        2013052112      ; serial
                        1h      ; refresh
                        30m     ; retry
                        7d      ; expiration
                        1h )    ; minimum
                NS      ns.example.com.
$ORIGIN s3.example.com
h1 IN   A 10.29.1.95
        A 10.29.0.142
        A 10.29.0.137
* IN    CNAME    @
```

   This configuration instructs the DNS to redirect all requests with URI *http//.s3.example.com/* to one of the endpoints listed in resource record `h1` (10.29.1.95, 10.29.0.142 or 10.29.0.137) in a cyclic (round-robin) manner.

8. Add nodes where object storage services will run to the configuration. To do this run the `ostor-ctl add-host` command on every such node:

```
# ostor-ctl add-host -H <internal_IP_address> -r <cluster_mount_point>/<ostor_dir>
```

This command will automatically detect and use the node's hostname and have the object storage agent service listen on an internal IP address. You will need to provide the object storage password set on step 3.

9. Create S3 gateway instances on chosen nodes with Internet access and external IP addresses.

> **Note:** For security reasons, make sure that only `nginx` can access the external network and that S3 gateways only listen on internal IP addresses.

```
# ostor-ctl add-s3gw -a <internal_IP_address>
```

where `<internal_IP_address>` is the internal IP address of the node with the gateway.

> **Note:** Port number is mandatory.

10. Launch object storage agent on each cluster node added to the object storage configuration.

```
# systemctl start ostor-agentd
# systemctl enable ostor-agentd
```

11. Make sure NS and OS services are bound to the nodes.

By default agents will try to assign NS and OS services to the nodes automatically in a round-robin manner. However, manual assignment is required if a new host has been added to the configuration, or if the current configuration is not optimized (for details, see *Manually Binding Services to Nodes* on page 29.

You can check the current binding configuration with the `ostor-ctl agent-status` command. For example:

```
# ostor-ctl agent-status
TYPE     SVC_ID              STATUS          UPTIME  HOST_ID           ADDRS
S3GW     8000000000000009    ACTIVE             527  fcbf5602197245da  127.0.0.1:9090
S3GW     8000000000000008    ACTIVE             536  4f0038db65274507  127.0.0.1:9090
S3GW     8000000000000007    ACTIVE             572  958e982fcc794e58  127.0.0.1:9090
OS       1000000000000005    ACTIVE             452  4f0038db65274507  10.30.29.124:39746
OS       1000000000000004    ACTIVE             647  fcbf5602197245da  10.30.27.69:56363
OS       1000000000000003    ACTIVE             452  4f0038db65274507  10.30.29.124:52831
NS       0800000000000002    ACTIVE             647  fcbf5602197245da  10.30.27.69:56463
NS       0800000000000001    ACTIVE             452  4f0038db65274507  10.30.29.124:53044
NS       0800000000000000    ACTIVE             647  fcbf5602197245da  10.30.27.69:37876
```

12. Install one `nginx` Web server per each S3 endpoint you need. On nodes where you install `nginx`, replace the contents of its configuration file `/etc/nginx/conf.d/nginx.conf` with the following (replace the IP addresses as required):

```
upstream s3 {
        server 127.0.0.1:9000; #S3 gateway 1 internal IP address
        server 127.0.0.2:9000; #S3 gateway 2 internal IP address
        server 127.0.0.3:9000; #S3 gateway 3 internal IP address
# Optional load balancing parameters (see
# http://nginx.org/en/docs/http/load_balancing.html)
}
server {
    listen       80;
    server_name  172.0.0.1; #S3 endpoint. If you have DNS configured,
    #replace the IP address with the corresponding hostname.
    client_max_body_size 5g;
    #charset koi8-r;
    #access_log  /var/log/nginx/log/host.access.log main;
    location / {
        fastcgi_pass_header Connection-close;
        fastcgi_pass s3;
        fastcgi_no_cache 1;
        include fastcgi_params;
        fastcgi_request_buffering off;
        fastcgi_max_temp_file_size 0;
}
```

13. Launch `nginx`:

```
# systemctl start nginx.service
# systemctl enable nginx.service
```

The object storage is deployed. Now you can add S3 users with the `ostor-s3-admin` tool. For example:

```
# ostor-s3-admin create-user -e user@email.com
Created user: email=user@email.com,user id=81d406fa613ad6c1
Key pair[0]: access key id=81d406fa613ad6c1S8HL,
secret access key=ya8iq3yrEYEhpErCkSmui6ifBghDDLdN2vso3sJn
```

The access key ID and secret access key pair, along with S3 endpoint, are required to connect to object storage from a client application.

To check that installation has been successful or just monitor object storage status, use the `ostor-ctl get-config` command. For example:

```
# ostor-ctl get-config
07-08-15 11:58:45.470 Use configuration service 'ostor'
SVC_ID             TYPE  URI
8000000000000006   S3GW  svc://1039c0dc90d64607/?address=127.0.0.1:9000
0800000000000000     NS  vstorage://cluster1/ostor/services/0800000000000000
1000000000000001     OS  vstorage://cluster1/ostor/services/1000000000000001
```

```
1000000000000002     OS  vstorage://cluster1/ostor/services/1000000000000002
1000000000000003     OS  vstorage://cluster1/ostor/services/1000000000000003
1000000000000004     OS  vstorage://cluster1/ostor/services/1000000000000004
8000000000000009   S3GW  svc://7a1789d20d9f4490/?address=127.0.0.1:9000
800000000000000c   S3GW  svc://7a1789d20d9f4490/?address=127.0.0.1:9090
```

3.2.1 Manually Binding Services to Nodes

You can manually bind services to nodes with the `ostor-ctl bind` command. You will need to specify the target node ID and one or more service IDs to bind to it. For example, the command:

```
# ostor-ctl bind -H 4f0038db65274507 -S 0800000000000001 \
-S 1000000000000003 -S 1000000000000005
```

binds services with IDs `800000000000001`, `1000000000000003`, and `1000000000000005` to a host with ID `4f0038db65274507`.

A service can only be bound to a host that is connected to the shared storage which stores that service's data. That is, the cluster name in service URI must match the cluster name in host URI.

For example, in a configuration with two shared storages `stor1` and `stor2` (see below) services with URIs starting with `vstorage://stor1` can only be bound to hosts `host510` and `host511` while services with URIs starting with `vstorage://stor2` can only be bound to hosts `host512` and `host513`.

```
# ostor-ctl get-config
SVC_ID             TYPE  URI
0800000000000000     NS  vstorage://stor1/s3-data/services/0800000000000000
0800000000000001     NS  vstorage://stor1/s3-data/services/0800000000000001
0800000000000002     NS  vstorage://stor2/s3-data/services/0800000000000002
1000000000000003     OS  vstorage://stor1/s3-data/services/1000000000000003
1000000000000004     OS  vstorage://stor2/s3-data/services/1000000000000004
1000000000000005     OS  vstorage://stor1/s3-data/services/1000000000000005
HOST_ID            HOSTNAME      URI
0fcbf5602197245da  host510:2530  vstorage://stor1/s3-data
4f0038db65274507   host511:2530  vstorage://stor1/s3-data
958e982fcc794e58   host512:2530  vstorage://stor2/s3-data
953e976abc773451   host513:2530  vstorage://stor2/s3-data
```

3.3 Managing S3 Users

The concept of S3 user is one of the base concepts of object storage along with those of object and bucket (container for storing objects). Amazon S3 protocol uses permissions model based on access control lists (ACLs) where each bucket and each object is assigned an ACL that lists all users with access to the given

resource and the type of this access (read, write, read ACL, write ACL). The list of users includes entity owner assigned to every object and bucket at creation. Entity owner has extra rights compared to other users, for example, bucket owner is the only one who can delete that bucket.

User model and access policies implemented in Virtuozzo Object Storage comply with the Amazon S3 user model and access policies.

User management scenarios in Virtuozzo Object Storage are largely based on the Amazon Web Services user management and include the following operations: create, query, delete users as well as generate, revoke user access key pairs.

3.3.1 Creating S3 Users

You can generate a unique random S3 user ID and an access key pair (S3 Access Key ID, S3 Secret Access Key) using the `ostor-s3-admin create-user` command. You need to specify a user email. For example:

```
# ostor-s3-admin create-user -e user@email.com
UserEmail:user@email.com
UserId:a49e12a226bd760f
KeyPair[0]:S3AccessKeyId:a49e12a226bd760fGHQ7
KeyPair[0]:S3SecretAccessKey:HSDu2DA00JNGjnRcAhLKfhrvlymzOVdLPsCK2dcq
Flags:none
```

S3 user ID is a 16-digit hexadecimal string. The generated access key pair is used to sign requests to the S3 object storage according to the Amazon S3 Signature Version 2 authentication scheme.

3.3.2 Listing S3 Users

You can list all object storage users with the `ostor-s3-admin query-users` command. Information for each user can take one or more sequential rows in the table. Additional rows are used to lists S3 access key pairs associated with the user. If the user does not have any active key pairs, minus signs are shown in the corresponding table cells. For example:

```
# ostor-s3-admin query-users
      S3 USER ID      S3 ACCESS KEY ID             S3 SECRET ACCESS KEY  S3 USER EMAIL
bf0b3b15eb7c9019  bf0b3b15eb7c9019I36Y                              ***  user2@abc.com
d866d9d114cc3d20  d866d9d114cc3d20G456                              ***  user1@abc.com
                  d866d9d114cc3d20D8EW                              ***
e86d1c19e616455                      -                                -  user3@abc.com
```

To output the list in XML, use the `-X` option; to output secret keys, use the `-a` option. For example:

```
# ostor-s3-admin query-users -a -X
<?xml version="1.0" encoding="UTF-8"?><QueryUsersResult><Users><User><Id>a49e12a226bd760f</Id><Ema
il>user@email.com</Email><Keys><OwnerId>0000000000000000</OwnerId><KeyPair><S3AccessKeyId>a49e12a2
26bd760fGHQ7</S3AccessKeyId><S3SecretAccessKey>HSDu2DA00JNGjnRcAhLKfhrvlymzOVdLPsCK2dcq</S3SecretA
ccessKey></KeyPair></Keys></User><User><Id>d7c53fc1f931661f</Id><Email>user@email.com</Email><Keys
><OwnerId>0000000000000000</OwnerId><KeyPair><S3AccessKeyId>d7c53fc1f931661fZLIV</S3AccessKeyId><S
3SecretAccessKey>JL7gt1OH873zR0Fzv8Oh9ZuA6JtCVnkgV7lET6ET</S3SecretAccessKey></KeyPair></Keys></Us
er></Users></QueryUsersResult>
```

3.3.3 Querying S3 User Information

To display information about the specified user, use the `ostor-s3-admin query-user-info` command. You need to specify either the user email (`-e`) or S3 ID (`-i`). For example:

```
# ostor-s3-admin query-user-info -e user@email.com
Query user: user id=d866d9d114cc3d20, user email=user@email.com
Key pair[0]: access key id=d866d9d114cc3d20G456,
secret access key=5EAne6PLL1jxprouRqq8hmfONMfgrJcOwbowCoTt
Key pair[1]: access key id=d866d9d114cc3d20D8EW,
secret access key=83tTsNAuuRyoBBqhxMFqHAC60dhKHtTCCkQe54zu
```

3.3.4 Disabling S3 Users

You can disable a user with the `ostor-s3-admin disable-user` command. You need to specify either the user email (`-e`) or S3 ID (`-i`). For example:

```
# ostor-s3-admin disable-user -e user@email.com
```

3.3.5 Deleting S3 Users

You can delete existing object storage users with the `ostor-s3-admin delete-user` command. Users who own any buckets cannot be deleted, so delete user's buckets first. You need to specify either the user email (`-e`) or S3 ID (`-i`). For example:

```
# ostor-s3-admin delete-user -i bf0b3b15eb7c9019
Deleted user: user id=bf0b3b15eb7c9019
```

3.3.6 Generating S3 User Access Key Pairs

You can generate a new access key pair for the specified user with the `ostor-s3-admin gen-access-key` command. The maximum of 2 active access key pairs are allowed per user (same as with the Amazon Web Services). You need to specify either the user email (`-e`) or S3 ID (`-i`). For example:

```
# ostor-s3-admin gen-access-key -e user@email.com
Generate access key: user id=d866d9d114cc3d20, access key id=d866d9d114cc3d20D8EW,
secret access key=83tTsNAuuRyoBBqhxMFqHAC60dhKHtTCCkQe54zu
```

Note: It is recommended to periodically revoke old and generate new access key pairs.

3.3.7 Revoking S3 User Access Key Pairs

You can revoke the specified access key pair of the specified user with the `ostor-s3-admin revoke-access-key` command. You need to specify the access key in the key pair you want to delete as well as the user email or S3 ID. For example:

```
# ostor-s3-admin revoke-access-key -e user@email.com -k de86d1c19e616455YIPU
Revoke access key: user id=de86d1c19e616455, access key id=de86d1c19e616455YIPU
```

Note: It is recommended to periodically revoke old and generate new access key pairs.

3.4 Managing S3 Buckets

All objects in Amazon S3-like storage are stored in containers named *buckets*. Buckets are addressed by names that are unique in the given object storage, so an S3 user of that object storage cannot create a bucket that has the same name as a different bucket in the same object storage. Buckets are used to:

- group and isolate objects from those in other buckets,
- provide ACL management mechanisms for objects in them,
- set per-bucket access policies, for example, versioning in the bucket.

You can manage buckets with the `ostor-s3-admin` tool as well as S3 API third-party S3 browsers like CyberDuck or DragonDisk.

> **Note:** As `ostor-s3-admin` commands are assumed to be issued by object storage administrators, they do not include any authentication or authorization checks.

3.4.1 Listing Bucket Contents

You can list bucket contents with a web browser. To do this, visit the URL that consists of the external DNS name for the S3 endpoint that you specified when creating the S3 cluster and the bucket name. For example, `mys3storage.example.com/mybucket`.

> **Note:** You can also copy the link to bucket contents by right-clicking it in CyberDuck, and then selecting Copy URL.

3.4.1.1 Managing Buckets from Command Line

3.4.2 Listing S3 Buckets

You can list all buckets in the S3 object storage with the `ostor-s3-admin list-all-buckets` command. For each bucket, the command shows owner, creation data, versioning status, and total size (the size of all objects stored in the bucket plus the size of all unfinished multipart uploads for this bucket). For example:

```
# ostor-s3-admin list-all-buckets
BUCKET   OWNER            CREATION_DATE            VERSIONING  TOTAL_SIZE NOTARY NOTARY_PROVIDER
bucker2  d7c53fc1f931661f  2017-04-03T17:11:44.000Z  none        0          off    0
bucket1  f8c55at83934321g  2017-04-03T17:11:33.000Z  none        0          off    0
```

To output the list in XML, use the `-X` option. For example:

```
# ostor-s3-admin list-all-buckets -X
<?xml version="1.0" encoding="UTF-8"?><ListBucketsResult><Buckets><Bucket><Name>bucker2</Name><Own
er>d7c53fc1f931661f</Owner><CreationDate>2017-04-03T17:11:44.000Z</CreationDate><Versioning>none</
Versioning><Notary>off</Notary><TotalSize>0</TotalSize></Bucket><Bucket><Name>bucket1</Name><Owner
>d7c53fc1f931661f</Owner><CreationDate>2017-04-03T17:11:33.000Z</CreationDate><Versioning>none</Ve
rsioning><Notary>off</Notary><TotalSize>0</TotalSize></Bucket></Buckets></ListBucketsResult>
```

To filter buckets by user who owns them, use the `-i` option. For example:

```
# ostor-s3-admin list-all-buckets -i d7c53fc1f931661f
BUCKET   OWNER             CREATION_DATE             VERSIONING  TOTAL_SIZE NOTARY NOTARY_PROVIDER
bucker2  d7c53fc1f931661f  2017-04-03T17:11:44.000Z  none        0          off    0
```

3.4.3 Querying S3 Bucket Information

You can query bucket metadata information and ACL with the `ostor-s3-admin query-bucket-info` command. For example, for `bucket1`:

```
# ostor-s3-admin query-bucket-info -b notary-bucket
BUCKET         OWNER             CREATION_DATE             VERSIONING  TOTAL_SIZE
notary-bucket  d7c53fc1f931661f  2017-03-24T08:24:53.000Z  none        166897
```

3.4.4 Changing S3 Bucket Owners

You can pass ownership of a bucket to the specified user with the `ostor-s3-admin change-bucket-owner` command. For example, to make user with ID `bf0b3b15eb7c9019` the owner of `bucket1`:

```
# ostor-s3-admin change-bucket-owner -b bucket1 -i bf0b3b15eb7c9019
Changed owner of the bucket bucket1. New owner bf0b3b15eb7c9019
```

3.4.5 Deleting S3 Buckets

You can delete the specified bucket with the `ostor-s3-admin delete-bucket` command. Deleting a bucket will delete all objects in it (including their old versions) as well as all unfinished multipart uploads for this bucket For example:

```
# ostor-s3-admin delete-bucket -b bucket1
Deleted bucket bucket1
```

3.5 Best Practices for Using Object Storage

This chapter describes recommendations on using various features of Virtuozzo Object Storage. These recommendations are called to help you enable additional functionality or improve convenience or performance of Virtuozzo Object Storage.

3.5.1 Bucket and Key Naming Policies

It is recommended to use bucket names that comply with DNS naming conventions:

- can be from 3 to 63 characters long,
- must start and end with a lowercase letter or number,
- can contain lowercase letters, numbers, periods (.), hyphens (-), and underscores (_),
- can be a series of valid name parts (described previously) separated by periods.

An object key can be a string of any UTF-8 encoded characters up to 1024 bytes long.

3.5.2 Improving Performance of PUT Operations

Object storage supports uploading of objects as large as 5 GB in size with a single PUT request. Upload performance can be improved, however, by splitting large objects into pieces and uploading them concurrently with multipart upload API. This approach will divide the load between multiple OS services.

It is recommended to use multipart uploads for objects larger than 5 MB.

3.6 Appendices

This chapter provides reference information related to Virtuozzo Object Storage.

3.6.1 Appendix A: Supported Amazon S3 REST Operations

The following Amazon S3 REST operations are currently supported by the Virtuozzo Storage implementation of the Amazon S3 protocol:

Service operations:

- GET Service

Bucket operations:

- DELETE Bucket
- GET Bucket (List Objects)

- GET Bucket acl
- GET Bucket location
- GET Bucket Object versions
- GET Bucket versioning
- HEAD Bucket
- List Multipart Uploads
- PUT Bucket
- PUT Bucket acl
- PUT Bucket versioning

Object operations:

- DELETE Object
- DELETE Multiple Objects
- GET Object
- GET Object ACL
- HEAD Object
- POST Object
- PUT Object
- PUT Object - Copy
- PUT Object acl
- Initiate Multipart Upload
- Upload Part
- Complete Multipart Upload
- Abort Multipart Upload
- List Parts

Note: For a complete list of Amazon S3 REST operations, see Amazon S3 REST API documentation.

3.6.2 Appendix B: Supported Amazon Request Headers

The following Amazon S3 REST request headers are currently supported by the Virtuozzo Storage implementation of the Amazon S3 protocol:

- x-amz-acl
- x-amz-delete-marker
- x-amz-grant-full-control
- x-amz-grant-read-acp
- x-amz-grant-read
- x-amz-grant-write
- x-amz-grant-write-acp
- x-amz-meta-**
- x-amz-version-id
- x-amz-copy-source
- x-amz-metadata-directive
- x-amz-copy-source-version-id

3.6.3 Appendix C: Supported Authentication Schemes

The following authentication scheme is supported by the Virtuozzo Storage implementation of the Amazon S3 protocol:

- Signature Version 2.
- Signature Version 4.

CHAPTER 4

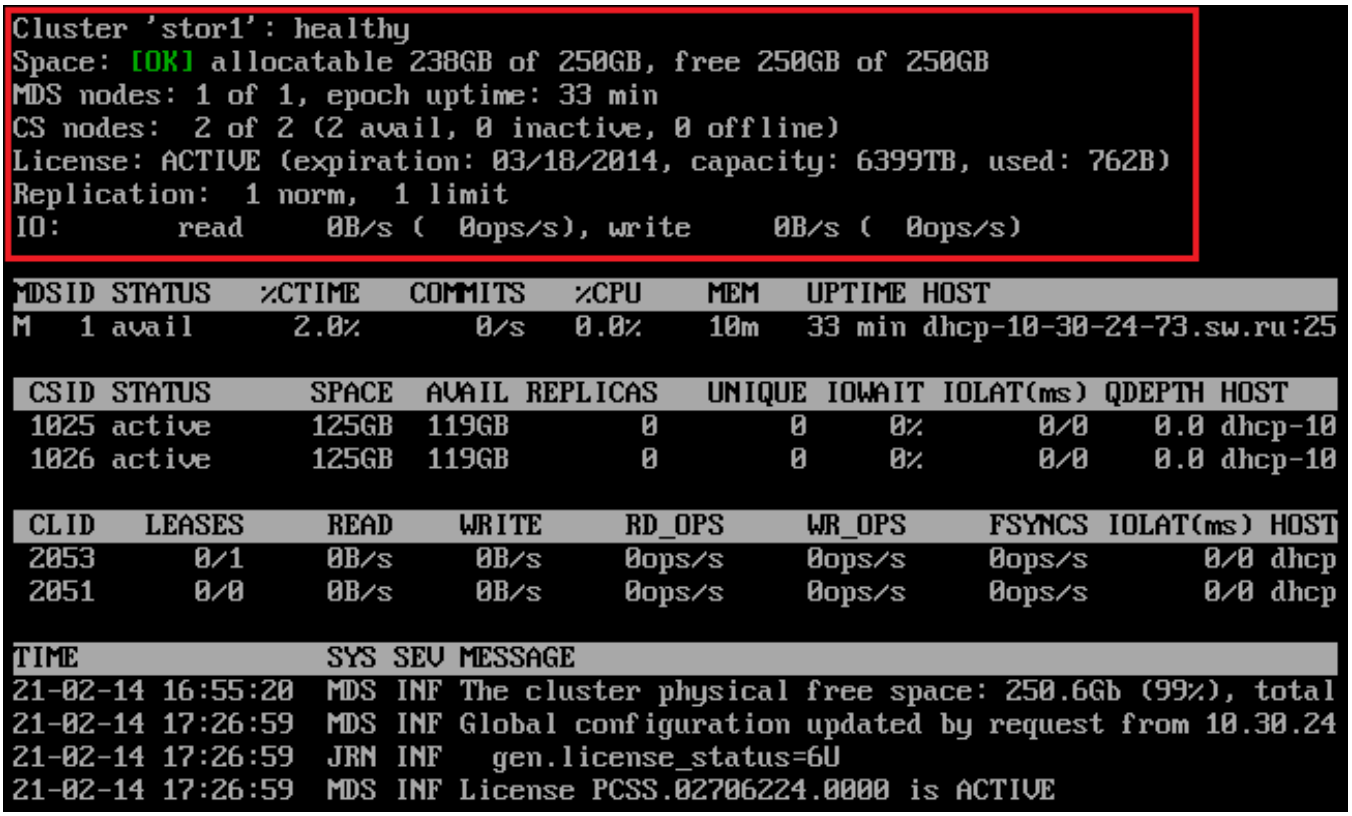
Monitoring Virtuozzo Storage Clusters

Monitoring a Virtuozzo Storage cluster is very important because it allows you to check the status and health of all computers in the cluster and react as necessary. This chapter explains how to monitor your Virtuozzo Storage cluster.

4.1 Monitoring General Cluster Parameters

By monitoring general parameters, you can get detailed information about all components of a Virtuozzo Storage cluster, its overall status and health. To display this information, use the `vstorage -c <cluster_name> top` command, for example:

4.1. Monitoring General Cluster Parameters



The command above shows detailed information about the `stor1` cluster. The general parameters (highlighted in red) are explained in the table below.

Parameter	Description
Cluster	Overall status of the cluster: • healthy. All chunk servers in the cluster are active. • unknown. There is not enough information about the cluster state (e.g., because the master MDS server was elected a while ago). • degraded. Some of the chunk servers in the cluster are inactive. • failure. The cluster has too many inactive chunk servers; the automatic replication is disabled. • SMART warning. One or more physical disks attached to cluster Nodes are in pre-failure condition. For details, see *Monitoring Physical Disks* on page 49

Parameter	Description
Space	Amount of disk space in the cluster: • free. Free physical disk space in the cluster. • allocatable. Amount of logical disk space available to clients. Allocatable disk space is calculated on the basis of the current replication parameters and free disk space on chunk servers. It may also be limited by license. **Note:** For more information on monitoring and understanding disk space usage in clusters, see *Understanding Disk Space Usage* on page 43
MDS nodes	Number of active MDS servers as compared to the total number of MDS servers configured for the cluster.
epoch time	Time elapsed since the MDS master server election.
CS nodes	Number of active chunk servers as compared to the total number of chunk servers configured for the cluster. The information in parentheses informs you of the number of • Active chunk servers (avail.) that are currently up and running in the cluster. • Inactive chunk servers (inactive) that are temporarily unavailable. A chunk server is marked as inactive during its first 5 minutes of inactivity. • Offline chunk servers (offline) that have been inactive for more than 5 minutes. A chunk server changes its state to offline after 5 minutes of inactivity. Once the state is changed to offline, the cluster starts replicating data to restore the chunks that were stored on the offline chunk server.
License	Key number under which the license is registered on the Key Authentication server and license state.
Replication	Replication settings. The normal number of chunk replicas and the limit after which a chunk gets blocked until recovered.
IO	Disks IO activity in the cluster: • Speed of read and write I/O operations, in bytes per second. • Number of read and write I/O operations per second.

4.2 Monitoring Metadata Servers

MDS servers are a critical component of any Virtuozzo Storage cluster, and monitoring the health and state of MDS servers is a very critical task. To monitor MDS servers, use the `vstorage -c <cluster_name> top` command, for example:

```
Cluster 'stor1': healthy
Space: [OK] allocatable 238GB of 250GB, free 250GB of 250GB
MDS nodes: 1 of 1, epoch uptime: 33 min
CS nodes:  2 of 2 (2 avail, 0 inactive, 0 offline)
License: ACTIVE (expiration: 03/18/2014, capacity: 6399TB, used: 762B)
Replication:  1 norm,  1 limit
IO:       read     0B/s (  0ops/s), write     0B/s (  0ops/s)

MDSID STATUS   %CTIME   COMMITS   %CPU    MEM   UPTIME HOST
M   1 avail      2.0%       0/s   0.0%    10m   33 min dhcp-10-30-24-73.sw.ru:25

 CSID STATUS      SPACE  AVAIL REPLICAS  UNIQUE IOWAIT IOLAT(ms) QDEPTH HOST
 1025 active      125GB  119GB        0       0     0%       0/0    0.0 dhcp-10
 1026 active      125GB  119GB        0       0     0%       0/0    0.0 dhcp-10

 CLID   LEASES     READ    WRITE    RD_OPS    WR_OPS    FSYNCS IOLAT(ms) HOST
 2053      0/1     0B/s     0B/s    0ops/s    0ops/s    0ops/s       0/0 dhcp
 2051      0/0     0B/s     0B/s    0ops/s    0ops/s    0ops/s       0/0 dhcp

TIME                SYS SEV MESSAGE
21-02-14 16:55:20  MDS INF The cluster physical free space: 250.6Gb (99%), total
21-02-14 17:26:59  MDS INF Global configuration updated by request from 10.30.24
21-02-14 17:26:59  JRN INF   gen.license_status=6U
21-02-14 17:26:59  MDS INF License PCSS.02706224.0000 is ACTIVE
```

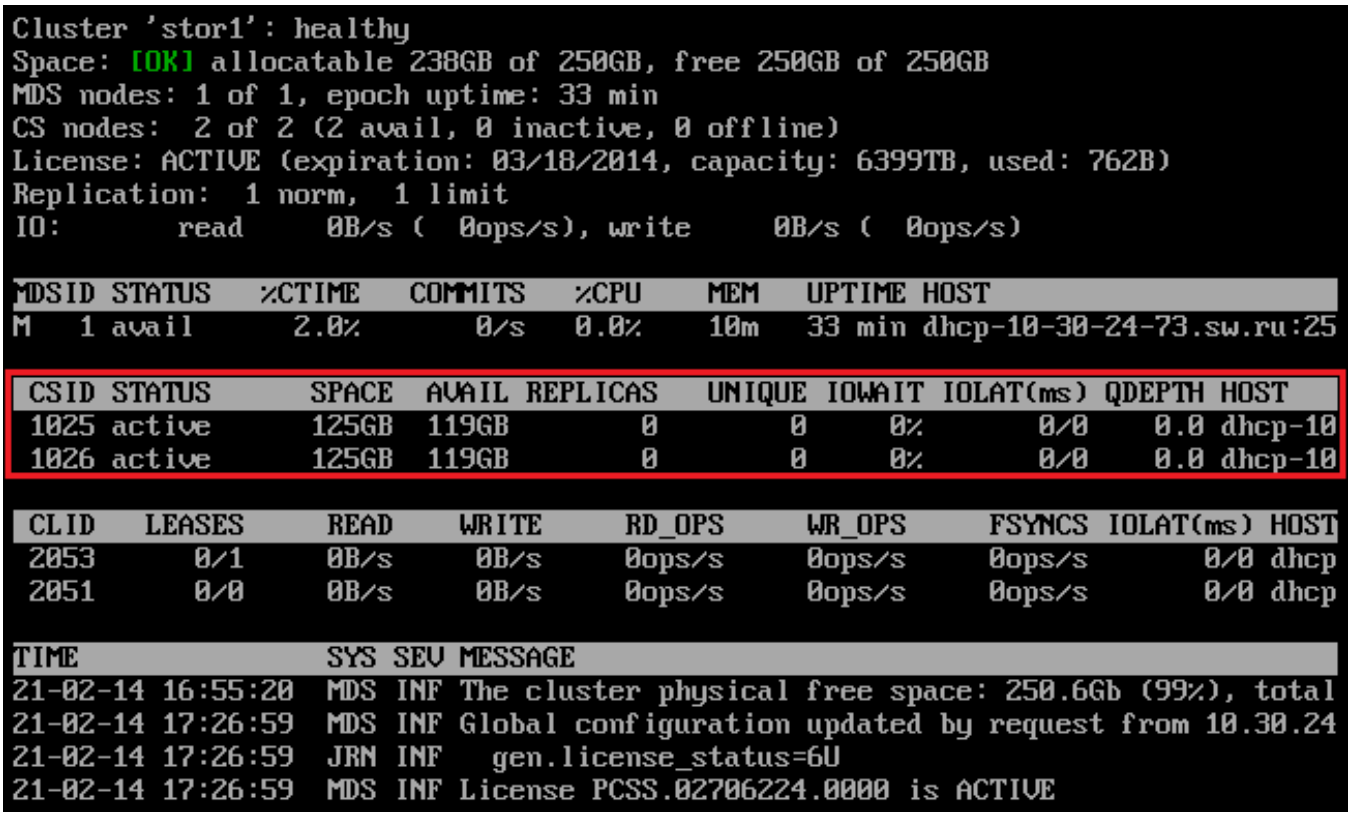
The command above shows detailed information about the `stor1` cluster. The monitoring parameters for MDS servers (highlighted in red) are explained in the table below:

Parameter	Description
MDSID	MDS server identifier (ID). The letter “M” before ID, if present, means that the given server is the master MDS server.
STATUS	MDS server status.
%CTIME	Total time the MDS server spent writing to the local journal.
COMMITS	Local journal commit rate.
%CPU	MDS server activity time.
MEM	Amount of physical memory the MDS server uses.

Parameter	Description
UPTIME	Time elapsed since the last MDS server start.
HOST	MDS server hostname or IP address.

4.3 Monitoring Chunk Servers

By monitoring chunk servers, you can keep track of the disk space available in a Virtuozzo Storage cluster. To monitor chunk servers, use the `vstorage -c <cluster_name> top` command, for example:



The command above shows detailed information about the `stor1` cluster. The monitoring parameters for chunk servers (highlighted in red) are explained in the table below:

Parameter	Description
CSID	Chunk server identifier (ID).

Parameter	Description
STATUS	Chunk server status: • active. The chunk server is up and running. • Inactive. The chunk server is temporarily unavailable. A chunk server is marked as inactive during its first 5 minutes of inactivity. • offline. The chunk server is inactive for more than 5 minutes. After the chunk server goes offline, the cluster starts replicating data to restore the chunks that were stored on the affected chunk server. • dropped. The chunk serve was removed by the administrator.
SPACE	Total amount of disk space on the chunk server.
FREE	Free disk space on the chunk server.
REPLICAS	Number of replicas stored on the chunk server.
IOWAIT	Percentage of time spent waiting for I/O operations being served.
IOLAT	Average/maximum time, in milliseconds, the client needed to complete a single IO operation during the last 20 seconds.
QDEPTH	Average chunk server I/O queue depth.
HOST	Chunk server hostname or IP address.
FLAGS	The following flags may be shown for active chunk servers: • J: The CS uses a write journal. • C: Checksumming is enabled for the CS. Checksumming lets you know when a third party changes the data on the disk. • D: Direct I/O, the normal state for a CS without a write journal. • c: The chunk server's write journal is clean, there is nothing to commit from the write journaling SSD to the HDD where the CS is located.

4.3.1 Understanding Disk Space Usage

Usually, you get the information on how disk space is used in your cluster with the `vstorage top` command. This command displays the following disk-related information: total space, free space, and allocatable space. For example:

```
# vstorage -c stor1 top
connected to MDS#1
```

```
Cluster 'stor1': healthy
Space: [OK] allocatable 180GB of 200GB, free 1.6TB of 1.7TB
...
```

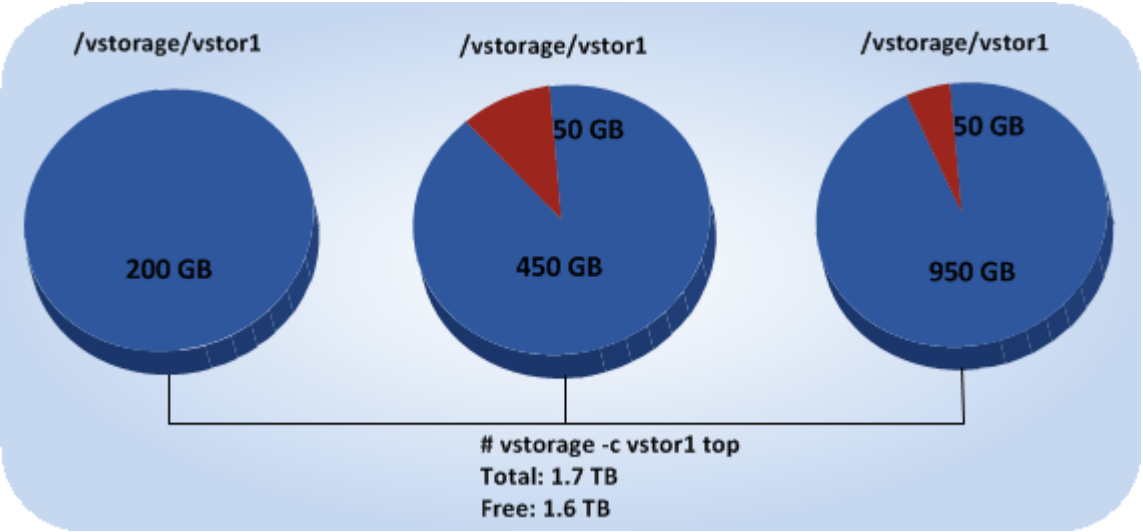
In this command output:

- 1.7TB is the total disk space in the `stor1` cluster. The total disk space is calculated on the basis of used and free disk space on all partitions in the cluster. Used disk space includes the space occupied by all data chunks and their replicas plus the space occupied by any other files stored on the cluster partitions.

  Let us assume that you have a 100 GB partition and 20 GB on this partition are occupied by some files. Now if you set up a chunk server on this partition, this will add 100 GB to the total disk space of the cluster, though only 80 GB of this disk space will be free and available for storing data chunks.

- 1.6TB is the free disk space in the `stor1` cluster. Free disk space is calculated by subtracting the disk space occupied by data chunks and any other files on the cluster partitions from the total disk space.

  For example, if the amount of free disk space is 1.6 TB and the total disk space is 1.7 TB, this means that about 100 GB on the cluster partitions are already occupied by some files.



- `allocatable 180GB of 200GB` is the amount of free disk space that can used for storing data chunks. See **Understanding allocatable disk space** below for details.

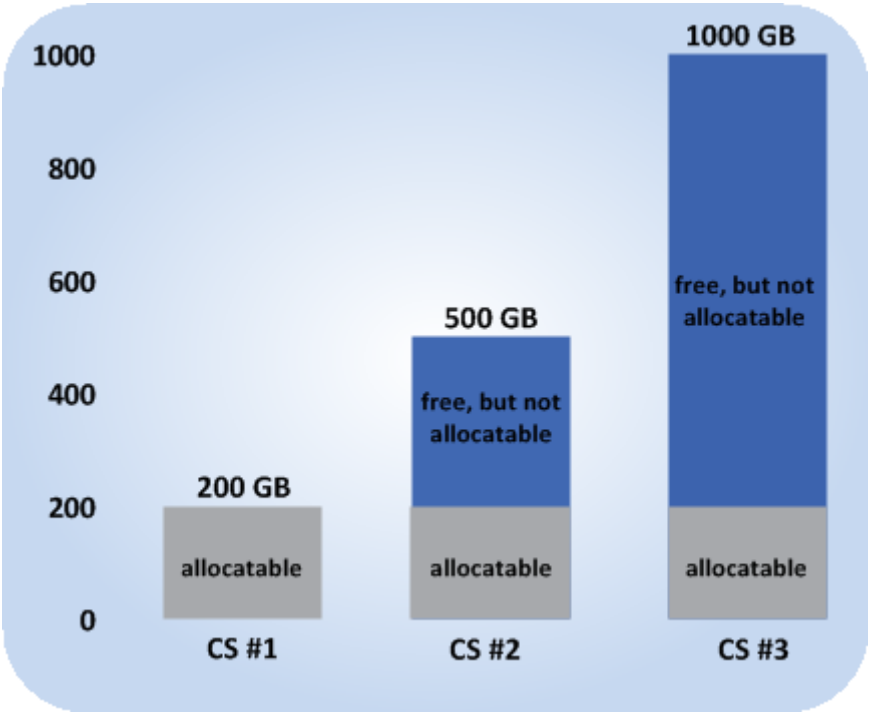
4.3.1.1 Understanding Allocatable Disk Space

When monitoring disk space information in the cluster, you also need to pay attention to the space reported by the `vstorage top` utility as *allocatable*. Allocatable space is the amount of disk space that is free and can be

used for storing user data. Once this space runs out, no data can be written to the cluster.

To better understand how allocatable disk space is calculated, let us consider the following example:

- The cluster has 3 chunk servers. The first chunk server has 200 GB of disk space, the second one — 500 GB, and the third one — 1 TB.
- The default replication factor of 3 is used in the cluster, meaning that each data chunk must have 3 replicas stored on three different chunk servers.



In this example, the available disk space will equal 200 GB, that is, set to the amount of disk space on the smallest chunk server:

```
# vstorage -c stor1 top
connected to MDS#1
Cluster 'stor1': healthy
Space: [OK] allocatable 180GB of 200GB, free 1.6TB of 1.7TB
...
```

This is explained by the fact that in this cluster configuration each server is set to store one replica for each data chunk. So once the disk space on the smallest chunk server (200 GB) runs out, no more chunks in the cluster can be created until a new chunk server is added or the replication factor is decreased.

If you now change the replication factor to 2, the `vstorage top` command will report the available disk space as 700 GB:

```
# vstorage set-attr -R /vstorage/stor1 replicas=2:1
# vstorage -c stor1 top
connected to MDS#1
Cluster 'stor1': healthy
Space: [OK] allocatable 680GB of 700GB, free 1.6TB of 1.7TB
...
```

The available disk space has increased because now only 2 replicas are created for each data chunk and new chunks can be made even if the smallest chunk server runs out of space (in this case, replicas will be stored on a bigger chunk server).

> **Note:** Allocatable disk space may also be limited by license.

4.3.1.2 Viewing Space Occupied by Data Chunks

To view the total amount of disk space occupied by all user data in the cluster, run the `vstorage top` command and press the V key on your keyboard. Once you do this, your command output should look like the following:

```
# vstorage -c stor1 top
Cluster 'stor1': healthy
Space: [OK] allocatable 180GB of 200GB, free 1.6TB of 1.7TB
MDS nodes: 1 of 1, epoch uptime: 2d  4h
CS nodes:  3 of 3 (3 avail, 0 inactive, 0 offline)
Replication:  2 norm,  1 limit,  4 max
Chunks: [OK] 38 (100%) healthy,  0 (0%) degraded,  0 (0%) urgent,
             0 (0%) blocked,  0 (0%) offline,  0 (0%) replicating,
             0 (0%) overcommitted,  0 (0%) deleting,  0 (0%) void
FS:  1GB in 51 files, 51 inodes,  23 file maps,  38 chunks,  76 chunk replicas
...
```

> **Note:** The **FS** field shows the size of all user data in the cluster without consideration for replicas.

4.3.2 Exploring Chunk States

The table below lists all possible states a chunk can have.

4.3. Monitoring Chunk Servers

Status	Description
healthy	Percentage of chunks that have enough active replicas. The normal state of chunks.
replicating	Percentage of chunks which are being replicated. Write operations on such chunks are frozen until replication ends.
offline	Percentage of chunks all replicas of which are offline. Such chunks are completely inaccessible for the cluster and cannot be replicated, read from or written to. All requests to an offline chunk are frozen until a CS that stores that chunk's replica goes online. Get offline chunk servers back online as fast as possible to avoid losing data.
void	Percentage of chunks that have been allocated but never used yet. Such chunks contain no data. It is normal to have some void chunks in the cluster.
pending	Percentage of chunks that must be replicated immediately. For a write request from client to a chunk to complete, the chunk must have at least the set minimum amount of replicas. If it does not, the chunk is blocked and the write request cannot be completed. As blocked chunks must be replicated as soon as possible, the cluster places them in a special high-priority replication queue and reports them as pending.
blocked	Percentage of chunks which have fewer active replicas than the set minimum amount. Write requests to a blocked chunk are frozen until it has at least the set minimum amount of replicas. Read requests to blocked chunks are allowed, however, as they still have some active replicas left. Blocked chunks have higher replication priority than degraded chunks. Having blocked chunks in the cluster increases the risk of losing data, so postpone any maintenance on working cluster nodes and get offline chunk servers back online as fast as possible.
degraded	Percentage of chunks with the number of active replicas lower than normal but equal to or higher than the set minimum. Such chunks can be read from and written to. However, in the latter case a degraded chunk becomes urgent.
urgent	Percentage of chunks which are degraded and have non-identical replicas. Replicas of a degraded chunk may become non-identical if some of them are not accessible during a write operation. As a result, some replicas happen to have the new data while some still have the old data. The latter are dropped by the cluster as fast as possible. Urgent chunks do not affect information integrity as the actual data is stored in at least the set minimum amount of replicas.

Status	Description
standby	Percentage of chunks that have one or more replicas in the standby state. A replica is marked standby if it has been inactive for no more than 5 minutes.
overcommitted	Percentage of chunks that have more replicas than normal. Usually these chunks appear after the normal number of replicas has been lowered or a lot of data has been deleted. Extra replicas are eventually dropped, however, this process may slow down during replication.

4.4 Monitoring Clients

By monitoring clients, you can check the status and health of servers that you use to access virtual machines and Containers. To monitor clients, use the `vstorage -c <cluster_name> top` command, for example:

```
Cluster 'stor1': healthy
Space: [OK] allocatable 238GB of 250GB, free 250GB of 250GB
MDS nodes: 1 of 1, epoch uptime: 33 min
CS nodes:  2 of 2 (2 avail, 0 inactive, 0 offline)
License: ACTIVE (expiration: 03/18/2014, capacity: 6399TB, used: 762B)
Replication:  1 norm,  1 limit
IO:       read     0B/s (  0ops/s), write     0B/s (  0ops/s)

MDSID STATUS   %CTIME   COMMITS   %CPU    MEM   UPTIME HOST
M   1 avail      2.0%       0/s   0.0%    10m   33 min dhcp-10-30-24-73.sw.ru:25

 CSID STATUS      SPACE  AVAIL REPLICAS  UNIQUE IOWAIT IOLAT(ms) QDEPTH HOST
 1025 active      125GB  119GB        0       0     0%       0/0    0.0 dhcp-10
 1026 active      125GB  119GB        0       0     0%       0/0    0.0 dhcp-10

 CLID   LEASES     READ    WRITE     RD_OPS     WR_OPS     FSYNCS IOLAT(ms) HOST
 2053      0/1     0B/s     0B/s     0ops/s     0ops/s     0ops/s       0/0 dhcp
 2051      0/0     0B/s     0B/s     0ops/s     0ops/s     0ops/s       0/0 dhcp

TIME                SYS SEV MESSAGE
21-02-14 16:55:20  MDS INF The cluster physical free space: 250.6Gb (99%), total
21-02-14 17:26:59  MDS INF Global configuration updated by request from 10.30.24
21-02-14 17:26:59  JRN INF   gen.license_status=6U
21-02-14 17:26:59  MDS INF License PCSS.02706224.0000 is ACTIVE
```

The command above shows detailed information about the `stor1` cluster. The monitoring parameters for clients (highlighted in red) are explained in the table below:

Parameter	Description
CLID	Client identifier (ID).
LEASES	Average number of files opened for reading/writing by the client and not yet closed, for the last 20 seconds.
READ	Average rate, in bytes per second, at which the client reads data, for the last 20 seconds.
WRITE	Average rate, in bytes per second, at which the client writes data, for the last 20 seconds.
RD_OPS	Average number of read operations per second the client made, for the last 20 seconds.
WR_OPS	Average number of write operations per second the client made, for the last 20 seconds.
FSYNCS	Average number of sync operations per second the client made, for the last 20 seconds.
IOLAT	Average/maximum time, in milliseconds, the client needed to complete a single IO operation, for the last 20 seconds.
HOST	Client hostname or IP address.

4.5 Monitoring Physical Disks

The S.M.A.R.T. status of physical disks is monitored by the `smartctl` tool installed along with Virtuozzo. The tool is run every 10 minutes as a `cron` job also added during Virtuozzo installation. The `smartctl` tool polls all physical disks attached to Hardware Nodes in the cluster, including caching and journaling SSDs, and reports the results to the MDS server.

Note: For the tool to work, enable the S.M.A.R.T. functionality in Node's BIOS.

You can view disk poll results for the last 10 minutes in the output of the `vstorage top` command. For example:

```
Cluster 'stor1': healthy, SMART warning
Space: [OK] allocatable 100GB (+778GB unlicensed) of 926GB, free 924GB of 926GB
MDS nodes: 1 of 1, epoch uptime: 7d 22h
CS nodes:  2 of 2 (2 avail, 0 inactive, 0 offline)
Replication:  1 norm,  1 limit
IO:       read     0B/s (  0ops/s), write     0B/s (  0ops/s)

MDSID STATUS   %CTIME   COMMITS   %CPU    MEM   UPTIME HOST
M   1 avail      0.0%       0/s   0.0%    48m   7d 22h pcs36.qa.sw.ru:2510

 CSID STATUS      SPACE  AVAIL REPLICAS   UNIQUE IOWAIT IOLAT(ms) QDEPTH HOST
 1025 active      9.1GB  7.1GB        0        0     0%       0/0    0.0 pcs36.q
 1026 active      916GB  870GB        0        0     0%       0/0    0.0 pcs36.q

 CLID   LEASES     READ    WRITE     RD_OPS     WR_OPS     FSYNCS IOLAT(ms) HOST

TIME                SYS SEV MESSAGE
01-07-14 16:42:19  MON WRN CS#1026 was stopped
01-07-14 16:42:26  JRN INF MDS#1 at 10.29.2.16:2510 became master
01-07-14 16:42:26  MDS WRN License not installed, please add license using comma
01-07-14 16:42:29  MON WRN MDS#1 was stopped
01-07-14 16:42:44  MDS INF CS#1025, CS#1026 are active
01-07-14 16:42:53  MDS INF The cluster is healthy with 2 active CS
01-07-14 16:42:53  MDS INF The cluster physical free space: 925.0Gb (99%), total
```

If the **SMART warning** message is shown in the main table, one of the physical disks is in pre-failure condition according to S.M.A.R.T. Press **d** to switch to the disks table to see more details. For example:

```
Cluster 'stor1': healthy, SMART warning
Space: [OK] allocatable 100GB (+778GB unlicensed) of 926GB, free 924GB of 926GB
MDS nodes: 1 of 1, epoch uptime: 7d 22h
CS nodes:  2 of 2 (2 avail, 0 inactive, 0 offline)
Replication:  1 norm,  1 limit
IO:       read     0B/s (  0ops/s), write     0B/s (  0ops/s)

    DISK SMART  TEMP CAPACITY          SERIAL                  MODEL HOST
     sdc    OK   27C    931GB      1374X80PS       TOSHIBA DT01ACA100 pcs36.qa
     sde  Warn   31C    931GB  MSE5235V36ZHWU  Hitachi HDS721010DLE630 pcs36.qa
```

The disks table shows the following parameters:

Parameter	Description
DISK	Disk name assigned by operating system.

Parameter	Description
SMART	Disk's S.M.A.R.T. status: • OK: The disk is healthy. • Warn: The disk is in pre-failure condition. Pre-failure condition means that at least one of these S.M.A.R.T. counters is nonzero: • Reallocated Sector Count • Reallocated Event Count • Current Pending Sector Count • Offline Uncorrectable
TEMP	Disk temperature in Celsius.
CAPACITY	Disk capacity.
SERIAL	Disk serial number.
MODEL	Disk model.
HOST	Disk's host address.

Note: To disable S.M.A.R.T. disk monitoring, delete the corresponding `cron` job.

4.6 Monitoring Event Logs

You can use the `vstorage -c <cluster_name> top` utility to monitor significant events happening in a Virtuozzo Storage cluster, for example:

```
Cluster 'stor1': healthy
Space: [OK] allocatable 238GB of 250GB, free 250GB of 250GB
MDS nodes: 1 of 1, epoch uptime: 33 min
CS nodes:  2 of 2 (2 avail, 0 inactive, 0 offline)
License: ACTIVE (expiration: 03/18/2014, capacity: 6399TB, used: 762B)
Replication:  1 norm,  1 limit
IO:       read     0B/s (  0ops/s), write     0B/s (  0ops/s)

MDSID STATUS   %CTIME   COMMITS   %CPU    MEM   UPTIME HOST
M   1 avail      2.0%       0/s   0.0%    10m   33 min dhcp-10-30-24-73.sw.ru:25

 CSID STATUS      SPACE  AVAIL REPLICAS   UNIQUE IOWAIT IOLAT(ms) QDEPTH HOST
 1025 active      125GB  119GB        0        0     0%       0/0    0.0 dhcp-10
 1026 active      125GB  119GB        0        0     0%       0/0    0.0 dhcp-10

 CLID   LEASES      READ     WRITE     RD_OPS     WR_OPS     FSYNCS IOLAT(ms) HOST
 2053      0/1      0B/s      0B/s      0ops/s     0ops/s     0ops/s       0/0 dhcp
 2051      0/0      0B/s      0B/s      0ops/s     0ops/s     0ops/s       0/0 dhcp

TIME                 SYS SEV MESSAGE
21-02-14 16:55:20  MDS INF The cluster physical free space: 250.6Gb (99%), total
21-02-14 17:26:59  MDS INF Global configuration updated by request from 10.30.24
21-02-14 17:26:59  JRN INF   gen.license_status=6U
21-02-14 17:26:59  MDS INF License PCSS.02706224.0000 is ACTIVE
```

The command above shows the latest events in the `stor1` cluster. The information on events (highlighted in red) is given in the table with the following columns:

Column	Description
TIME	Time when the event happened.
SYS	Component of the cluster where the event happened (e.g., MDS for an MDS server or JRN for local journal).
SEV	Event severity.
MESSAGE	Event description.

4.6.1 Exploring Basic Events

The table below describes the basic events displayed when you run the `vstorage top` utility.

4.6. Monitoring Event Logs

Event	Severity	Description
MDS#<N> (<addr>:<port>) lags behind for more than 1000 rounds	JRN err	Generated by the MDS master server when it detects that MDS#<N> is stale. This message may indicate that some MDS server is very slow and lags behind.
MDS#<N> (<addr>:<port>) didn't accept commits for *M* sec	JRN err	Generated by the MDS master server if MDS#<N> did not accept commits for *M* seconds. MDS#<N> gets marked as *stale*. This message may indicate that the MDS service on MDS#<N> is experiencing a problem. The problem may be critical and should be resolved as soon as possible.
MDS#<N> (<addr>:<port>) state is outdated and will do a full resync	JRN err	Generated by the MDS master server when MDS#<N> will do a full resync. MDS#<N> gets marked as *stale*. This message may indicate that some MDS server was too slow or disconnected for such a long time that it is not really managing the state of metadata and has to be resynchronized. The problem may be critical and should be resolved as soon as possible.
MDS#<N> at <addr>:<port> became master	JRN info	Generated every time a new MDS master server is elected in the cluster. Frequent changes of MDS masters may indicate poor network connectivity and may affect the cluster operation.
The cluster is healthy with *N* active CS	MDS info	Generated when the cluster status changes to *healthy* or when a new MDS master server is elected. This message indicates that all chunk servers in the cluster are active and the number of replicas meets the set cluster requirements.

Event	Severity	Description
The cluster is degraded with *N* active, *M* inactive, *K* offline CS	MDS warn	Generated when the cluster status changes to *degraded* or when a new MDS master server is elected. This message indicates that some chunk servers in the cluster are • inactive (do not send any registration messages) or • offline (are inactive for a period longer than mds.wd.offline_tout = 5min (by default)).
The cluster failed with *N* active, *M* inactive, *K* offline CS (mds.wd.max_offline_cs=<n>)	MDS err	Generated when the cluster status changes to *failed* or when a new MDS master server is elected. This message indicates that the number of offline chunk servers exceeds mds.wd.max_offline_cs (2 by default). When the cluster fails, the automatic replication is not scheduled any more. So the cluster administrator must take some actions to either repair failed chunk servers or increase the mds.wd.max_offline_cs parameter. Setting the value of this parameter to 0 disables the failed mode completely.
The cluster is filled up to <N>%	MDS info/warn	Shows the current space usage in the cluster. A warning is generated if the disk space consumption equals or exceeds 80%. It is important to have spare disk space for data replicas if one of the chunk servers fails.
Replication started, N chunks are queued	MDS info	Generated when the cluster starts the automatic data replication to recover the missing replicas.
Replication completed	MDS info	Generated when the cluster finishes the automatic data replication.

Event	Severity	Description
CS#<N> has reported hard error on *path*	MDS warn	Generated when the chunk server CS#<N> detects disk data corruption. You are recommended to replace chunk servers with corrupted disks as soon as possible with new ones and to check the hardware for errors.
CS#<N> has not registered during the last *T* sec and is marked as inactive/offline	MDS warn	Generated when the chunk server CS#<N> has been unavailable for a while. In this case, the chunk server first gets marked as inactive. After 5 minutes, the state is changed to offline, which starts the automatic replication of data to restore the replicas that were stored on the offline chunk server.
Failed to allocate *N* replicas for '*path*' by request from <<addr>:<port>> - *K* out of *M* chunks servers are av ailable	MDS warn	Generated when the cluster cannot allocate chunk replicas, for example, when it runs out of disk space.
Failed to allocate *N* replicas for '*path*' by request from <<addr>:<port>> since only *K* chunk servers are regis tered	MDS warn	Generated when the cluster cannot allocate chunk replicas because not enough chunk servers are registered in the cluster.

4.7 Monitoring the Status of Replication Parameters

When you configure replication parameters, keep in mind that the new settings do not come into effect immediately. For example, increasing the default replication parameter for data chunks may take some time to complete, depending on the new value of this parameter and the number of data chunks in the cluster.

To check that the new replication parameters have been successfully applied to your cluster:

1. Run the `vstorage -c <cluster_name> top` command.
2. Press the V key on your keyboard to display additional information about the cluster. Your command output should look similar to the following:

```
# vstorage -c stor1 top
connected to MDS#1
Cluster 'stor1': healthy
Space: [OK] allocatable 200GB of 211GB, free 211GB of 211GB
MDS nodes: 1 of 1, epoch uptime: 2h 21m
CS nodes:  2 of 2 (2 avail, 0 inactive, 0 offline)
License: PCSS.02444715.0000 is ACTIVE, 6399TB capacity
Replication:  3 norm,  2 limit
Chunks: [OK] 431 (100%) healthy,  0 (0%) degraded,  0 (0%) urgent,
             0 (0%) blocked,  0 (0%) offline,  0 (0%) replicating,
             0 (0%) overcommitted,  0 (0%) deleting,  0 (0%) void
...
```

3. Check the **Chunks** field for the following:

   - When decreasing the replication parameters, look for chunks that are in the **overcommitted** or **deleting** state. If the replication process is complete, no chunks with these states should be present in the output.
   - When increasing the replication parameters, look for chunks that are in the blocked or urgent state. If the replication process is complete, no chunks with these states should be present in the output. Besides, when the process is still in progress, the value of the healthy parameter is less than 100%.

> **Note:** For more information on available chunk statutes, see *Exploring Chunk States* on page 46.

CHAPTER 5

Managing Cluster Security

This chapter describes some situations that may affect your cluster security.

5.1 Security Considerations

This section describes the security limitations you should keep in mind when deploying a Virtuozzo Storage cluster.

Traffic sniffing

Virtuozzo Storage does not protect you from traffic sniffing. Anyone who has access to your network can capture and analyze the data being sent and received through your network.

To learn how to keep your data secure, see *Securing Server Communication in Clusters* on page 58.

Absence of users and groups

Virtuozzo Storage does not use the concept of users and groups, providing specific users and groups with access to specific parts of a cluster. Anyone authorized to access a cluster can access all its data.

Non-encrypted data on disks

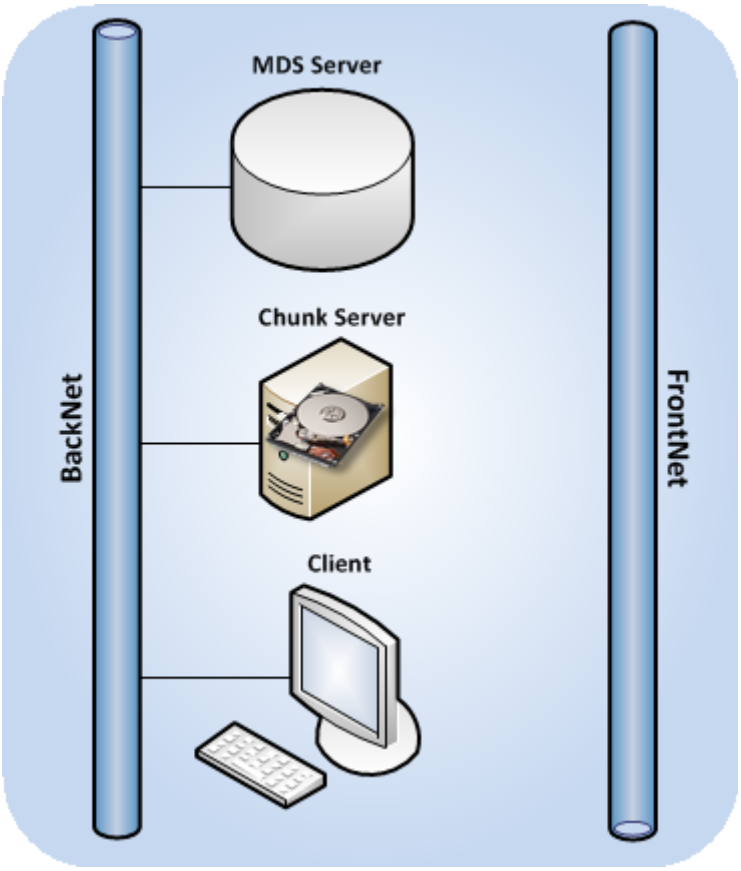
Virtuozzo Storage does not encrypt data stored in a cluster. Attackers can immediately see the data once they gain access to a physical disk drive.

5.2 Securing Server Communication in Clusters

A Virtuozzo Storage cluster can contain three types of servers:

- MDS servers
- chunk servers
- clients

During cluster operation, the servers communicate with each other. To secure their communication, you should keep all servers on an isolated private network—BackNet. The figure below shows an example cluster configuration where all servers are set up on the BackNet.



The process of deploying such a configuration can be described as follows:

1. You create the cluster by making the MDS server and specifying one of its IP addresses:

```
# vstorage -c Cluster-Name make-mds -I -a MDS-IP-Address -r Journal-Directory -p
```

The specified address will then be used for MDS interconnection and intercommunication with the other servers in the cluster.

2. You set up a chunk server:

```
# vstorage -c Cluster-Name make-cs -r CS-Directory
```

Once it is created, the chunk server connects to the MDS server and binds to the IP address it uses to establish the connection. If the chunk server has several networks cards, you can explicitly assign the chunk server to the IP address of a specific network card so that all communication between the chunk and MDS servers is carried out via this IP address.

To bind a chunk server to a custom IP address, you pass the `-a` option to the `vstorage make-cs` command when you create the chunk server:

```
# vstorage make-cs -r CS-Directory -a Custom-IP-Address
```

> **Note:** A custom IP address must belong to the BackNet not to compromise your cluster security.

3. You mount the cluster on the client:

```
# vstorage-mount -c Cluster-Name Mount-Directory
```

Once the cluster is mounted, the client connects to the MDS and chunk server IP addresses.

This example configuration provides a high level of security for server communication because the MDS server, the chunk server, and the client are located on the isolated BackNet and cannot be compromised.

5.3 Password-based Authentication

Virtuozzo Storage uses password-based authentication to enhance security in clusters. You have to pass the authentication phase before you can add a new server to the cluster.

Password-based authentication works as follows:

1. You set the authentication password when you create the first MDS server in the cluster. The password you specify is encrypted and saved into the `/etc/vstorage/clusters/stor1/auth_digest.key` file on the server.

2. You add new MDS servers, chunk servers, or clients to the cluster and use the `vstorage auth-node` command to authenticate them. During authentication, you use the password you set when creating the first MDS server.
3. Virtuozzo Storage compares the provided password with the one stored on the first MDS server, and if the passwords match, successfully authenticates the server.

For each physical server, authentication is a one-time process. Once a server is authenticated in the cluster (for example, when you configure it as an MDS server), the `/etc/vstorage/clusters/stor1/auth_digest.key` file is created on the authenticated server. When you set up this server as another cluster component (e.g., as a chunk server), the cluster checks that the `auth_digest.key` file is present and does not require you to authenticate the server again.

CHAPTER 6

Maximizing Cluster Performance

This chapter describes recommendations for maximizing the performance of your Virtuozzo Storage clusters.

> **Note:** Also consider updating hardware nodes in the cluster.

6.1 Carrying Out Performance Benchmarking

When testing the performance of a Virtuozzo Storage cluster and comparing it with non-Virtuozzo Storage setups:

- Compare configurations with similar redundancy levels. For example, it is incorrect to compare the performance of a cluster with two or three replicas per data chunk with a standalone server that does not use any data redundancy, like RAID 1, 10, or 5.
- Take into account the usage of file system interfaces. Keep in mind that mounting a Virtuozzo Storage cluster using the FUSE interface provides a convenient view into the cluster but is not optimal for performance. Therefore, do benchmarks from inside Containers and virtual machines.
- Keep in mind that the data replication factor affects the cluster performance: clusters with two replicas are slightly faster than those with three replicas.

6.2 Checking Data Flushing

Before creating the cluster, you are recommended to check that all storage devices (hard disk drives, solid disk drives, RAIDs, etc.) you plan to include in your cluster can successfully flush data to disk when the server power goes off unexpectedly. Doing so will help you detect possible problems with devices that may lose data stored in their cache in the event of a power failure.

Virtuozzo Storage ships with a special tool, `vstorage-hwflush-check`, for checking how a storage device flushes data to disk in an emergency case such as power outage. The tool is implemented as a client/server utility:

- **Client**. The client continuously writes blocks of data to the storage device. When a data block is written, the client increases a special counter and sends it to the server that keeps it.
- **Server**. The server keeps track of the incoming counters from the client so that it always knows the counter number the client will send next. If the server receives the counter that is less than the one already stored on the server (e.g., because the power was turned off and the storage device did not flush the cached data to disk), the server reports an error.

To check that a storage device can successfully flush data to disk when the power fails, follow the procedure below:

On the server part:

1. On a Virtuozzo Storage server other than the one with the storage device to check, install the `vstorage-hwflush-check` tool. This tool is part of the `vstorage-ctl` package and can be installed with this command:

   ```
   # yum install vstorage-ctl
   ```

2. Run the `vstorage-hwflush-check` server:

   ```
   # vstorage-hwflush-check -l
   ```

On the client part:

1. On the Virtuozzo Storage server with the storage device you want to check, install the `vstorage-hwflush-check` tool:

   ```
   # yum install vstorage-ctl
   ```

2. Run the `vstorage-hwflush-check` client, for example:

   ```
   # vstorage-hwflush-check -s vstorage1.example.com -d /vstorage/stor1-ssd/test -t 50
   ```

where

- `-s vstorage1.example.com` is the hostname of the computer where the `vstorage-hwflush-check` server is running.
- `-d /vstorage/stor1-ssd/test` defines the directory to use for testing data flushing. During its execution, the client creates a file in this directory and writes data blocks to it.
- `-t 50` sets the number of threads for the client to write data to disk. Each thread has its own file and counter. You can increase the number of threads (max. 200) to test your system in more stressful conditions. You can also specify other options when running the client. For more information on available options, see the `vstorage-hwflush-check` man page.

3. Wait for 10-15 seconds or more and power off the computer where the client is running, and then turn it on again.

> **Note:** The **Reset** button does not turn off the power so you need to press the **Power** button or pull out the power cord to switch off the computer.

4. Restart the client by executing the same command you used to run it for the first time:

```
# vstorage-hwflush-check -s vstorage1.example.com -d /vstorage/stor1-ssd/test -t 50
```

Once launched, the client reads all written data, determines the version of data on the disk, and then restarts the test from the last valid counter. It then sends this valid counter to the server, and the server compares it with the latest counter it has. You may see output like:

```
id<N>:<counter_on_disk> -> <counter_on_server>
```

which means one of the following:

- If the counter on disk is lower than the counter on server, it means that the storage device has failed to flush the data to disk. Avoid using this storage device in production—especially for CS or journals—as you risk losing data.
- If the counter on disk is higher than the counter on server, it means that the storage device has flushed the data to disk but the client has failed to report it to the server. The network may be too slow or the storage device may be too fast for the set number of load threads so you may consider increasing it. This storage device can be used in production.
- If both counters are equal, it means the storage device has flushed the data to disk and the client has reported it to the server. This storage device can be used in production.

To be on the safe side, repeat the procedure several times. Once you check your first storage device, continue with all remaining devices you plan to use in the cluster.

6.3 Using 1 GbE and 10 GbE Networks

1 Gbit/s Ethernet networks can deliver 110-120 MB/s, which is close to a single drive performance on sequential I/O. Since several drives on a single server can deliver higher throughput than a single 1 Gbit/s Ethernet link, networking may become a bottleneck.

However, in real-life applications and virtualized environments, sequential I/O is not common (backups mainly) and most of the I/O operations are random. Thus, typical HDD throughput is usually much lower, close to 10-20 MB/s, according to statistics accumulated from hundreds of servers by a number of major hosting companies.

Based on these two observations, we recommend to use one of the following network configurations (or better):

- A 1 Gbit/s link per each 2 HDDs on the Hardware Node. Although if you have 1 or 2 HDDs on a Hardware Node, two bonded network adapters are still recommended for better reliability (see *Setting Up Network Bonding* on page 65).
- A 10 Gbit/s link per Hardware Node for the maximum performance.

The table below illustrates how these recommendations may apply to a Hardware Node with 1 to 6 HDDs:

HDDs	1 GbE Links	10 GbE Links
1	1 (2 for HA)	1 (2 for HA)
2	1 (2 for HA)	1 (2 for HA)
3	2	1 (2 for HA)
4	2	1 (2 for HA)
5	3	1 (2 for HA)
6	3	1 (2 for HA)

Note:

1. For the maximum sequential I/O performance, we recommend to use one 1Gbit/s link per each hard drive, or one 10Gbit/s link per Hardware Node.
2. It is not recommended to configure 1 Gbit/s network adapters to use non-default MTUs (e.g., 9000-byte jumbo frames). Such settings require switch configuration and often lead to human errors. 10 Gbit/s network adapters, on the other hand, need to be configured to use jumbo frames to achieve full performance.
3. For maximum efficiency, use the `balance-xor` bonding mode with the `layer3+4` hash policy. If you want to use the `802.3ad` bonding mode, also configure your switch to use the `layer3+4` hash policy.

6.4 Setting Up Network Bonding

Bonding multiple network interfaces together provides the following benefits:

1. High network availability. If one of the interfaces fails, the traffic will be automatically routed to the working interface(s).
2. Higher network performance. For example, two Gigabit interfaces bonded together will deliver about 1.7 Gbit/s or 200 MB/s throughput. The required number of bonded storage network interfaces may depend on how many storage drives are on the Hardware Node. For example, a rotational HDD can deliver up to 1 Gbit/s throughput.

To configure a bonding interface, do the following:

1. Create the `/etc/modprobe.d/bonding.conf` file containing the following line:

   alias bond0 bonding

2. Create the `/etc/sysconfig/network-scripts/ifcfg-bond0` file containing the following lines:

```
DEVICE=bond0
ONBOOT=yes
BOOTPROTO=none
IPV6INIT=no
USERCTL=no
BONDING_OPTS="mode=balance-xor xmit_hash_policy=layer3+4 miimon=300 downdelay=300 \
updelay=300"
NAME="Storage net0"
NM_CONTROLLED=no
```

```
IPADDR=xxx.xxx.xxx.xxx
PREFIX=24
```

Note:

1. Make sure to enter the correct values in the `IPADDR` and `PREFIX` lines.
2. The `balance-xor` mode is recommended, because it offers both fault tolerance and better performance. For more details, see the documents listed below.

3. Make sure the configuration file of each Ethernet interface you want to bond (e.g., `/etc/sysconfig/network-scripts/ifcfg-eth0`) contains the lines shown in this example:

```
DEVICE="eth0"
BOOTPROTO=none
NM_CONTROLLED="no"
ONBOOT="yes"
TYPE="Ethernet"
HWADDR=xx:xx:xx:xx:xx:xx
MASTER=bond0
SLAVE=yes
USERCTL=no
```

4. Bring up the `bond0` interface:

```
# ifup bond0
```

5. Use `dmesg` output to verify that `bond0` and its slave Ethernet interfaces are up and links are ready.

Note: More information on network bonding is provided in the *Red Hat Enterprise Linux Deployment Guide* and *Linux Ethernet Bonding Driver HOWTO.*

6.5 Improving High-Capacity HDD Performance

Unlike older hard disks with 512-byte sectors, many modern HDDs (3TB and more in capacity) use 4KB physical sectors. In certain cases, this can greatly reduce system performance (by 3-4 times) due to extra Read-Modify-Write (RMW) cycles required to align the source write request. Why this happens? When an operating system issues an unaligned write request, the HDD has to align the beginning and end of that

request to 4KB boundaries. To do this, the HDD reads the request's head and tail ranges to determine an even number of sectors to modify. For example, on a request to write a 4KB block at a 2KB offset, HDD will read the 0-2KB and 6-8KB ranges to modify the entire 0-8KB data range.

The typical reasons of poor performance with 4KB sector HDDs are:

1. Host OS file system unaligned on the 4KB boundary. The `make-cs` command of Virtuozzo Storage tries to detect and report such issues to the administrator in advance, but be aware that the `fdisk` utility is not recommended for partitioning HDDs. You should use `parted` instead.
2. Unaligned writes (e.g., 1KB) performed by guest OS. Many legacy operating systems, like Microsoft Windows XP and Windows Server 2003 or Red Hat Enterprise Linux 5.x, have unaligned partitions by default and generate unaligned I/O patterns which are quite slow on both Virtuozzo Storage and actual HDDs with 4KB sectors. If you plan running such legacy operating systems, consider the following:
   - Using smaller HDDs with 512-byte sectors, or use SSD journaling for CS services which mitigates the issue to some extent.
   - Aligning OS partitions properly.

You can check for unaligned write operations in the cluster by as follows:

1. Run the `vstorage top` or `stat` command. For example:

```
# vstorage -c stor1 top
```

2. Press **i** to display the **RMW** and **JRMW** columns in the CS part of the `top` output.
3. Check the **RMW** or **JRMW** counters, which are explained below.
   - When SSD journaling is used, the **RMW** counter shows the number of requests which lead to Read-Modify-Write cycles, while the **JRMW** counter shows the number of Read-Modify-Write cycles mitigated by the use of SSD journals.
   - When SSD journaling is not used, the **JRMW** counter shows the number of unaligned requests which potentially generate Read-Modify-Write cycles on the HDD in question.

6.6 Disabling Inter-Tier Data Allocation

If a storage tier runs out of free space, Virtuozzo Storage will attempt to temporarily use the space of the lower tiers down to the lowest. If the lowest tier also becomes full, Virtuozzo Storage will attempt to use a

higher one. If you add more storage to the original tier later, the data, temporarily stored elsewhere, will be moved to the tier where it should have been stored originally.

Mixing tier workloads is not recommended as it may decrease cluster performance. To prevent this, you can disable automatic data migration between tiers after making sure that each tier have enough free space. Execute the following command on any cluster node:

```
# vstorage -c cluster1 set-config mds.alloc.strict_tier=1
```