FlashGrid® Storage Fabric
Version 17.01

Deployment and Maintenance Guide
(on-premises deployments)
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1 Introduction

This document is intended for system and database administrators who deploy and maintain on-premises storage for Oracle RAC based on FlashGrid Storage Fabric. The FlashGrid Storage Fabric software enables open and flexible architecture for Oracle RAC that is equally efficient in both small and large clusters.

FlashGrid Storage Fabric highlights

- Primary shared storage based on standard NVMe PCIe SSDs, SAS SSDs, or locally attached virtual disks
- Physical storage located inside the database nodes (converged nodes) or in separate storage nodes
- VMs or standard x86 servers used as database and storage nodes
- FlashGrid Storage Fabric software manages SSD devices and connectivity, integrates with Oracle ASM
- Oracle ASM manages data, volumes, mirroring, snapshots
- 2-way or 3-way mirroring of data across different nodes
- Choice of Ethernet (generic or ROCE) or InfiniBand/RDMA for network connectivity
- FlashGrid Read-Local Technology minimizes network overhead by serving reads from local SSDs

New in FlashGrid Storage Fabric version 17.01

- Support for quorum nodes on VMs that have limited network connectivity to database nodes
- Strict Read-Local mode for extended distance clusters and cloud
- Ephemeral SSD support in cloud deployments
2 Compatibility

- Supported InfiniBand HCAs: Mellanox ConnectX-3 or ConnectX-4
- Supported RoCE NICs: Mellanox ConnectX-4
- Oracle Linux 7.2/7.3 or Red Hat Enterprise Linux 7.2/7.3
  - Red Hat kernel version 3.10.0-327.36.1.el7.x86_64 or later
  - Oracle UEK R4 Update 2 kernel version 4.1.12-61.1.28.el7uek or later
  - Note: RDMA support is not yet available with Red Hat kernel versions 3.10.0-514.el7.x86_64 or later
- Oracle Grid Infrastructure 12.1.0.2 with the latest patches
- Oracle Database 11.2.0.x or 12.1.0.x with the latest patches

3 Steps for Deploying an Oracle RAC Cluster on FlashGrid Storage Fabric

The following steps outline the process of deploying FlashGrid. More detailed information for each step is provided in the subsequent sections of the guide.

1. Get familiar with the FlashGrid architecture and determine the following:
   - Storage inside the database nodes (hyper-converged architecture) or in separate storage nodes
   - The number of database nodes and storage nodes
   - The number and type (Normal Redundancy or High Redundancy) of ASM disk groups
   - Placement of Grid Infrastructure files (GRID disk group) – on a FlashGrid disk group or on an external storage
   - The number of quorum disks required and their location
   - Network type and topology
2. Prepare each node of the cluster
   a. Install and configure OS
   b. Install the FlashGrid software
   c. If required, install RDMA drivers and utilities
   d. Configure network
   e. If required, create LVM volumes for quorum disks and/or disks for GRID disk group
   f. If required, configure external storage for quorum disks and/or disks for GRID disk group
3. Configure the FlashGrid cluster
4. If GRID disk group uses FlashGrid disks then
   a. Install and configure Grid Infrastructure cluster
   b. During GI installation create the GRID disk group using temporary GRID disks
   c. After GI installation replace the temporary disks with permanent GRID disks using flashgrid-fix-ocr-dg tool
5. Create ASM disk group(s) for data
6. Create database(s) or ACFS file system(s) on the disk group(s)

Note: Grid Infrastructure can be installed before configuring FlashGrid if an external storage is used for the GRID disk group.
4 FlashGrid Storage Fabric Architecture

4.1 Hyper-converged architecture or separate storage nodes

With 2-node or 3-node clusters a converged configuration with storage located inside the database nodes is usually optimal. The following picture shows an example of such configuration with three database nodes.

Placing storage in separate dedicated storage servers may be preferred in clusters with 4+ database nodes or if the database nodes do not have enough room for SSDs, for example, with blades or 1U database servers.
4.2 Shared Access

With the help of FlashGrid software each ASM instance can access each of the SSDs in the cluster. Each SSD is visible in the OS as /dev/flashgrid/nodename.drivename device where nodename is the name of the node where the SSD is physically located.

4.3 Data Mirroring

The FlashGrid architecture leverages Oracle ASM’s existing capabilities for mirroring data. In Normal Redundancy mode each block of data has two mirrored copies. In High Redundancy mode each block of data has three mirrored copies. Each ASM disk group is divided into failure groups – one failure group per node. Each disk is configured to be a part of a failure group that corresponds to the node where the disk is physically located. ASM makes sure that mirrored copies of a data block are placed on different failure groups.

In Normal Redundancy mode the cluster can withstand loss of one (converged or storage) node without interruption of service. In High Redundancy mode the cluster can withstand loss of two (converged or storage) nodes without interruption of service.
4.4 FlashGrid Read-Local™ Technology

In hyper-converged clusters the read traffic can be served from local SSDs at the speed of the PCIe bus instead of travelling over the network. In 2-node clusters with 2-way mirroring or 3-node clusters with 3-way mirroring 100% of the read traffic is served locally because each node has a full copy of all data. Because of the reduced network traffic the write operations are faster too. As a result, even 10 GbE network fabric can be sufficient for achieving outstanding performance in such clusters for both data warehouse and OLTP workloads. For example, a 3-node cluster with four NVMe SSDs per node can provide 30 GB/s of read bandwidth, even on a 10 GbE network.

4.5 Strict Read-Local Mode

ASM does not allow reads from disks that are resynchronizing data (SYNCING state) after being offline. As a result, if database is running on a node whose local disks are in SYNCING state, all reads will be performed remotely over the network. In cloud based or extended distance clusters that have relatively low network bandwidth this may result in lower performance of the database instance on a node that has just rebooted and is still resynchronizing its data.

Strict Read-Local mode prevents such performance asymmetry between nodes. When the Strict Read-Local mode is enabled, a database instance start will be delayed until its local disks are resynchronized.

Use the following commands to enable, disable, and show status of Strict Read-Local mode:

```
flashgrid-cluster strict-read-local-enable
flashgrid-cluster strict-read-local-disable
flashgrid-cluster strict-read-local-show
```

Note that in order to unmount a diskgroup while Strict Read-Local mode is enabled, `srvctl stop diskgroup` command with `-force` option must be used. Example:

```
    srvctl stop diskgroup -diskgroup DGNAME -node rac1,rac2 -force
```

4.6 Quorum Disks

In certain disk group configurations one or two additional quorum disks may be required depending on the number of nodes in the cluster. The quorum disks may be required even in disk groups that do not store Voting files. ASM uses quorum disks to store additional copies of metadata that can be used for arbitration in certain failure scenarios.

One quorum disks requires 300 MiB of space. The quorum disks generate very small amount of storage traffic and can be stored on any type of external shared storage. The quorum disks may be stored on storage that does not provide high
availability or redundancy. However, the storage for the quorum disks must be external to the FlashGrid nodes used for data storage.

Options for quorum disk placement:

- LVM volumes on dedicated quorum server(s), physical or VM
- LVM volumes on database nodes (for clusters with separate storage nodes)
- External iSCSI/FC/FCoE storage
- NFS (not supported for disk groups containing ACFS)

The following table shows how many quorum disks are required for a disk group depending on the disk group redundancy level and the number of converged or storage nodes in the cluster:

<table>
<thead>
<tr>
<th></th>
<th>2 nodes</th>
<th>3 nodes</th>
<th>4 nodes</th>
<th>5+ nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Redundancy</td>
<td>1 quorum disk</td>
<td>not needed</td>
<td>not needed</td>
<td>not needed</td>
</tr>
<tr>
<td>High Redundancy</td>
<td>N/A</td>
<td>2 quorum disks required</td>
<td>1 quorum disk</td>
<td>not needed</td>
</tr>
<tr>
<td>(with Voting Files)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Redundancy</td>
<td>N/A</td>
<td>2 quorum disks recommended</td>
<td>1 quorum disk recommended</td>
<td>not needed</td>
</tr>
<tr>
<td>(no Voting Files)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.7 Using External Storage in Combination with FlashGrid

Any type of external storage can be used in combination with FlashGrid storage including FC, FCoE, iSCSI, or NFS. The external storage can be used for storing data that does not require the tier-0 performance of the FlashGrid storage, e.g. Grid Infrastructure files, ASM quorum disks, Grid/Database home, backups, or archive logs. Separate ASM disk groups must be configured for any external storage.

4.8 Selecting Location for Grid Infrastructure Files (GRID disk group)

Two main options are available for the GRID disk group that contains Voting files, OCR, and MGMTDB:

- **An external storage: FC/FCoE/iSCSI SAN or NFS.** This option provides simplified installation and more flexibility by storing Grid Infrastructure files separately from the high performance FlashGrid storage. 20 GB capacity is sufficient in most cases with moderate performance requirements. The external storage must provide high availability. Two or three separate storage systems can be combined in a Normal or High Redundancy disk group to achieve high availability.

- **FlashGrid storage.** This option allows reduced dependency on any external storage. This option is preferred when there is no external storage available that can provide sufficient level of availability. In most cases, it is recommended to use LVM volumes on the system boot drives of the converged or storage nodes as disks for the GRID disk group. The use of LVM volumes eliminates the need for separate physical SSDs dedicated to the GRID disk group, thus making more SSD slots available for data.

4.9 Dependencies between FlashGrid and Oracle Services

The FlashGrid rpm installer creates a `systemd` dependency on `flashgrid_wait` service that delays OHAS/CRS start until all storage nodes in the FlashGrid cluster are online and all FlashGrid devices are connected. This dependency allows avoiding a situation where CRS tries to mount an ASM disk group before all storage devices are available. You can use `flashgrid-node stop-waiting` command to override this dependency and allow CRS to start while some FlashGrid devices are still node ready.

Note that if you try to start CRS manually while it is being blocked by the systemd dependency then subsequent attempts to start it may fail even after the dependency is cleared. If this happens, use `systemctl restart oracle-ohasd` command to start CRS.
4.10 Persistent Names and Permissions for ASM Disks

FlashGrid software provides persistent naming, sets device permissions, and configures multipathing for ASM disks managed by FlashGrid. There is no need to use ASMLib or UDEV rules for regular ASM disks managed by FlashGrid, including external iSCSI disks configured in FlashGrid. However, quorum disks located on external storage not managed by FlashGrid require persistent names, permissions, and multipathing configured separately outside of FlashGrid.

5 Installing and Configuring OS

5.1 Enabling Performance mode in system BIOS

It is recommended to configure Performance mode for CPUs in the system BIOS. With default settings a CPU can get into a power-saving mode that causes undesirable latencies.

5.2 Reserving space for LVM volumes during OS installation

In most cases it is recommended to reserve 30GiB of space on the system drive during OS installation. This reserved space can be used later for creating LVM volumes for quorum disks or for the GRID disk group. The space can be reserved in the default LVM volume group, as a separate partition, or as a separate hardware RAID volume. In case of a virtual node, an additional virtual disk can be used instead.

5.3 Setting Performance mode for CPU governor

It is recommended to set Performance mode for the CPU governor service. This will guarantee that the CPUs are always running at their maximum frequency and will help reduce latencies.

   # cpupower frequency-set --governor performance

5.4 Synchronizing clocks with NTPD

System clocks must be within 30 seconds between all nodes in the cluster. Configuring NTPD service is recommended before configuring FlashGrid cluster. Configure NTPD service according to the Oracle Grid Infrastructure requirements.

5.5 Configuring ASM device owner user and group

Before configuring FlashGrid cluster make sure that owner (e.g. ‘oracle’ or ‘grid’) and group (e.g. ‘asmadmin’) for Grid Infrastructure are configured on all nodes where ASM will be installed. FlashGrid will use these user and group in the disk device permissions.

5.6 Configuring key based SSH access

For configuring FlashGrid cluster you will need key based SSH access from one node of a cluster to a user account on all nodes, including quorum server(s), if any, and including the local node. Connecting as root is recommended if permitted by the existing security policies. Key based SSH access can be configured using ‘ssh-keygen’ command followed by ‘ssh-copy-id username@nodename’ command for each node.

Example of configuring key based access to root@ on three nodes (run as root on each node):

   # ssh-keygen -t rsa
   # for i in node1 node2 node3; do ssh-copy-id -i ~/.ssh/id_rsa.pub root@$i; done
6 Installing FlashGrid Storage Fabric Software

The FlashGrid Storage Fabric software is provided as a single RPM package. Additional open-source RPMs required by the FlashGrid software are provided in YUM repositories and as TAR packages. All RPMs must be installed on every node in a FlashGrid cluster including converged nodes, storage nodes, database nodes, and quorum server nodes.

To install the FlashGrid Storage Fabric software, complete the following steps on each node:

1. Download and install FlashGrid open source repository RPM from flashgrid.io/downloads/
   
   # yum install flashgrid-oss-repo-17.01-1.noarch.rpm

   Alternatively, you can download the open source packages as a TAR archive FlashGrid-17.01-opensrc-pkgs.tar.gz

2. Download the FlashGrid software RPM from flashgrid.io/downloads/

3. Download oracle-instantclient12.1-basic-12.1.0.2.0-1.x86_64.rpm from http://www.oracle.com/technetwork/topics/linuxx86-64soft-092277.html

4. Use YUM to install the downloaded RPMs and their dependencies:

   # yum install flashgrid-17.01.*.rpm oracle-instantclient12.1-basic-12.1.0.2.0-1.x86_64.rpm
7 Installing RDMA Drivers and Utilities for InfiniBand or RoCE

If you are planning to use RDMA with InfiniBand or RoCE then you must install RDMA drivers and utilities. The FlashGrid version 16.11 is validated with RDMA drivers from Mellanox OFED version 3.3 (RH 7.2 kernels) and version 3.4 (UEK R4u2 kernels). FlashGrid provides only those packages from the Mellanox OFED distribution that are required for FlashGrid operation.

Note: RDMA support is not yet available with Red Hat kernel version 3.10.0-514.el7.x86_64 or later.

To install RDMA drivers and utilities for Red Hat 7.2 kernels 3.10.0-327.y.z.el7.x86_64

1. Edit /etc/yum.repos.d/flashgrid-oss.repo and
   - Enable flashgrid-16.11-ofed3.3-rhel-7.2-repo repository
   - Disable flashgrid-16.11-ofed3.4-uek4-repo repository
   Alternatively, you can download the RPMs as an archive MOFED3.3-RH-OL-72.tar.gz from flashgrid.io/downloads/

2. Install the required Mellanox OFED RPMs:

   # yum install mlnx-ofa_kernel kmod-mlnx-ofa_kernel libibmad libibumad
   infiniband-diags

To install RDMA drivers and utilities for UEK4u2 kernels 4.1.12-61.y.z.el7uek.x86_64

1. Edit /etc/yum.repos.d/flashgrid-oss.repo and
   - Enable flashgrid-16.11-ofed3.4-uek4-repo repository
   - Disable flashgrid-16.11-ofed3.3-rhel-7.2-repo repository
   Alternatively, you can download the RPMs as an archive MOFED3.4-OL-73-UEK4u2.tar.gz from flashgrid.io/downloads/

2. Install the required Mellanox OFED RPMs:

   # yum install mlnx-ofa_kernel kmod-mlnx-ofa_kernel libibmad libibumad kmod-iser kmod-isert infiniband-diags
# 8 Configuring Storage Network

## 8.1 Sharing Network between FlashGrid and Oracle Private Network

FlashGrid supports sharing network interfaces with Oracle private network. However, in case of RAC deployments the performance impact on Cache Fusion operation must be carefully assessed.

## 8.2 Common Network Configuration Requirements

In all storage network topologies the following requirements must be met:

- Equal number of network interfaces must be configured on all converged/database/storage nodes of a cluster
  - Quorum server nodes can have a different number of network interfaces, typically only one.
  - Exceptions are possible, but require additional configuration steps. Contact FlashGrid for assistance.
- Network interfaces must have the same names on all converged/database/storage nodes of a cluster
  - Quorum server nodes can have network interfaces with different names.
  - Exceptions are possible, but require additional configuration steps. Contact FlashGrid for assistance.
- Each network interface must have a static IPv4 address
- Network interfaces with the same name (e.g. ‘em2’) must belong to the same IPv4 subnet.
- Use of jumbo frames (MTU=9000) is recommended on Ethernet networks. If using switches then before enabling jumbo frames on NICs, need to verify that switches also are configured to support jumbo frames.
- Routing between the subnets must be disabled – do not configure gateways.
  - If a Quorum server node has to be on a separate subnet then additional configuration steps are required. Contact FlashGrid for assistance.
- IPv4 multicast must be enabled within each subnet
- The following ports must be open between all nodes of a cluster:
  - TCP 3260
  - TCP 5557
  - TCP 8753

## 8.3 Storage Network Topology

The following subsections describe typical storage network topologies.

### 8.3.1 Direct back-to-back network links

This topology allows implementing a high-speed storage network interconnect (Ethernet or InfiniBand) without the additional cost of the high-speed network switches.

In production environments at least two network links must be used for redundancy between each pair of nodes. Using three or more links is possible for extra bandwidth. There is no need for the storage network links between database-only nodes. There is no need for the storage network links between storage-only nodes.

Each network link must be configured as a separate IP subnet (this applies to InfiniBand too). FlashGrid software provides multi-path and load balancing across multiple links. NIC bonding is not required.

### 8.3.2 A single switch (Ethernet or InfiniBand)

This topology should not be used in a mission-critical environment. A failure of the single switch may cause the cluster down time.

Each node must be connected to one or more ports of the switch. Connecting to more than one port adds port and cable redundancy and increases the total network bandwidth available to each node.
8.3.3 Two or more separate switches (Ethernet or InfiniBand), each node connected to all switches
Two separate switches are recommended for most configurations of 4 or more nodes per cluster. Three or more switches can be used for extra switch redundancy.

The switches should have no links between them. If links between the switches are required for purposes other than FlashGrid then the ports used for FlashGrid should be isolated in non-routable VLANs that do not include the inter-switch links.

Each node must be connected to all switches.

8.3.4 Two or more stacked Ethernet switches, each node connected to all switches
Stacked Ethernet switches may be configured with LACP link aggregation across the switches. In this scenario network link redundancy and load balancing is performed at the switch level. A single virtual network interface per node is configured in FlashGrid.

8.3.5 Two or three geographically separated sites
For geographically separated sites one non-routable VLAN per network interface must be configured. Each VLAN must span all sites and include a separate set of physical switches to ensure network connection redundancy. Extra care must be taken to ensure IP multicast is enabled within each VLAN across all sites.

8.4 Configuring Ethernet NICs (including RoCE)
Ethernet NICs can be configured using standard Network Manager tools. Alternatively, the NIC configuration files can be created manually in /etc/sysconfig/network-scripts/

Example of a manually created configuration file.

```bash
HWADDR=XX:XX:XX:XX:XX:XX
DEVICE=flashgrid
IPADDR=192.168.1. Node
PREFIX=24
BOOTPROTO=none
DEFROUTE=no
IPV4_FAILURE_FATAL=yes
IPV6INIT=no
ONBOOT=yes
NM_CONTROLLED=no
TYPE=Ethernet
MTU=9000
```
8.5 Configuring RoCE Services

To configure RoCE services

1. Edit `/etc/rdma/rdma.conf` and set the following parameters to `yes` and all other parameters to `no`:
   
   ```
   ISER_LOAD=yes
   ISERT_LOAD=yes
   ```

2. Enable `rdma` service

   ```
   # systemctl enable rdma
   ```

3. Disable `openibd` service

   ```
   # systemctl disable openibd
   ```

4. Reboot the system

5. Verify that the `rdma` service is in `active (exited)` state on every node:

   ```
   # systemctl status rdma
   ```

6. Run the following command on every node:

   ```
   # ibstat
   ```

7. In the `ibstat` output verify the following

   - All ports are visible
   - For all ports: *Physical State: LinkUp*
   - Rate corresponds to the speed of the Ethernet adapters and the switch. If the rate is lower then check that correct type of cable is used and the connectors are well seated.
   - For all ports: *State: Active*.

8.6 Configuring InfiniBand Services

8.6.1 Enabling InfiniBand Services

To enable InfiniBand services

1. Edit `/etc/rdma/rdma.conf` and set the following parameters to `yes` and all other parameters to `no`:

   ```
   IPOIB_LOAD=yes
   ISER_LOAD=yes
   ISERT_LOAD=yes
   RDS_LOAD=yes
   ```

2. Enable `rdma` service

   ```
   # systemctl enable rdma
   ```

3. Disable `openibd` service

   ```
   # systemctl disable openibd
   ```

4. Reboot the system

5. Verify that the `rdma` service is in `active (exited)` state on every node:
# systemctl status rdma

6. Run the following command on every node:

   # ibstat

7. In the `ibstat` output verify the following
   - All ports are visible
   - For all ports: **Physical State: LinkUp**
   - Rate corresponds to the speed of the InfiniBand adapters and the switch. If the rate is lower then check that correct type of cable is used and the connectors are well seated.
   - For all ports: **State: Active**.
     If State is **Polling** then check that cables are connected.
     If State is **Initializing** then this means that
       - in case of managed switches, the subnet(s) must be configured on the switch.
       - in case of back-to-back connections or unmanaged switches, OpenSM subnet manager service must be configured and started.

### 8.6.2 Configuring OpenSM Subnet Manager

The OpenSM service must be configured only if using back-to-back InfiniBand connections or unmanaged switches. If using managed switches then do not configure the OpenSM service, instead configure subnets on the switches.

To configure OpenSM service, use the following steps on every node:

1. Install OpenSM RPM from RHEL7 / OL7 repo:

   # yum install opensm

2. Add GUIDs for all ports to the OpenSM configuration file /etc/sysconfig/opensm:

   # echo 'GUIDS=\`ibstat -p | tr \n \`` > /etc/sysconfig/opensm

3. Enable OpenSM daemon

   # systemctl enable opensm

4. Start OpenSM daemon

   # systemctl start opensm

5. Verify that now State is **Active** for all ports

   # ibstat
8.6.3 Configuring IPoIB

In RDMA mode the FlashGrid software uses IPoIB only for management traffic, no user data is transferred over IP protocol. However, it is still important to have IPoIB configured on all InfiniBand ports that are used for FlashGrid storage network (and also for Oracle private network).

To configure IPoIB:

1. For each InfiniBand interface (ib0, ib1,..) edit the corresponding file /etc/sysconfig/network-scripts/ifcfg-ibX using the following template:

```
DEVICE=ibX
IPADDR=192.168.X.X
PREFIX=24
BOOTPROTO=none
DEFROUTE=no
IPV4_FAILURE_FATAL=yes
IPV6INIT=no
ONBOOT=yes
NM_CONTROLLED=no
TYPE=InfiniBand
CONNECTED_MODE=no
```

2. Restart the network

   `# systemctl restart network`

3. Verify that all interfaces are up and the correct IP addresses are assigned to them

   `# ip addr`

Note that in RDMA mode the MTU size is not applicable and there is no need to change it from the default.
9 Creating LVM Volumes for Quorum and GRID Disks

9.1 Choosing an LVM volume group

An LVM volume group with sufficient amount of free space is required if you need to create LVM volumes for quorum or GRID disks.

To check available LVM volume groups or to create a new volume group

1. Install LVM2 rpm if it is not installed
   
   # yum install lvm2

2. Check available volume group(s) and the amount of free space. For quorum disks you will need 300 MiB multiplied by the number of disk groups. For GRID disks you need 20 GiB.
   
   # vgdisplay

3. If no volume group or no free space is available, create a new volume group on any unused disk or partition
   
   # pvcreate /dev/<disk>
   # vgcreate <vgname> /dev/<disk>

9.2 Creating LVM volumes for quorum disks

If you are planning to have quorum disks located on database nodes or on quorum servers then you need to create one 300MiB LVM volume for each ASM disk group on each of the database nodes or quorum servers. The quorum disk volumes must have ‘quorum’ in either volume group name or logical volume name. Such volumes will be automatically shared by FlashGrid without additional configuration. The quorum disk volumes can be added before or after configuring the FlashGrid cluster.

To create LVM volumes for quorum disks

On each database node or quorum server create one volume for each disk group. Include word ‘quorum’ in the volume name unless volume group name already includes it.

Example for three disk groups:

# lvcreate <vgname> --size 300M --name quorum1
# lvcreate <vgname> --size 300M --name quorum2
# lvcreate <vgname> --size 300M --name quorum3

9.3 Creating LVM volumes for GRID disk group

If the GRID disk group is placed on FlashGrid disks then you need to create LVM volumes on each of the converged or storage nodes. The GRID disk volumes must have ‘grid’ in either volume group name or logical volume name. Such volumes will be automatically shared by FlashGrid without additional configuration. The grid disk volumes can be added before or after configuring the FlashGrid cluster, but they must be available before installing Grid Infrastructure.

To create LVM volumes for GRID disks

On each converged or storage node create one GRID disk volume and two temporary GRID disk volumes:

# lvcreate <vgname> --size 10G --name grid
# lvcreate <vgname> --size 5G --name grid-tmp1
# lvcreate <vgname> --size 5G --name grid-tmp2
10 Configuring FlashGrid Storage Fabric

Configuration of a FlashGrid Storage Fabric cluster is stored in /etc/flashgrid.cfg files on each node of the cluster. In most cases there is no need to edit the configuration files manually. FlashGrid Configuration Assistant tool provides an easy way for creating the configuration files.

It is important to remember that creating, changing, or erasing FlashGrid configuration does not change the contents of any ASM disks including ASM metadata. FlashGrid cluster configuration is stored separately from ASM disk group configuration and only determines how disks are shared between the nodes. However, extra care must be taken when changing FlashGrid cluster configuration while any ASM disk group is mounted. Accidentally removing access to any disk that is a member of a mounted disk group may lead to degraded data redundancy or to the disk group being dismounted by ASM.

Before configuring a FlashGrid cluster, verify the following prerequisites

- Time in synchronized between all nodes that will be included in the cluster
- Owner (e.g. ‘oracle’ or ‘grid’) and group (e.g. ‘asmadmin’) for Grid Infrastructure are configured on all nodes where ASM will be installed.
- Your current user account must have key based SSH access to a user account on all nodes of the cluster, including quorum server(s), if any, and including the local node. Connecting as root is recommended if permitted by the existing security policies.
- If Grid Infrastructure is already installed then the CRS services must be stopped.

To configure a FlashGrid cluster

1. Run flashgrid-ca on any node of the cluster
2. Complete all steps of the FlashGrid Configuration Assistant following the instructions on each screen.
3. Run ‘flashgrid-cluster’ command to check status of all nodes in the cluster and network connectivity between the nodes.
4. If any of the nodes shows Warning or Critical status then on that node run ‘flashgrid-node’ command to find the source of the problem. Note that a Warning state is expected on those nodes that have the ASM node role and no Grid Infrastructure installed.
5. On each node run ‘flashgrid-node test-alerts’ to check that email alerts work.
FlashGrid Configuration Assistant: Create new configuration

No FlashGrid cluster configuration found on this node. To add this node to an existing FlashGrid cluster, run `flashgrid-ca` on one of the configured nodes.

Press Next to create a new cluster configuration.

Next Quit

FlashGrid Configuration Assistant: Configuring cluster name and nodes

Cluster name: MyCluster

Member nodes (use only short host names):
  rac1 ASH+Storage
  rac2 ASH+Storage
  rac3 Quorum
  <Add>

[ ] Configure virtual network links to Quorum node(s)
Virtual network prefix: 16.107.0.0/16

User for SSH connections to the cluster nodes: root
Note: a non-root user can save the configuration files on the local node only.
Note: the current user root must have key based SSH access configured to the selected user account on all nodes, including the local node.
Keep the default paths if all NVMe drives must be shared by FlashGrid.

Edit NVMe drive paths only if some NVMe drives must be excluded. The exclude paths take precedence over the include paths. Use only persistent paths based on slot numbers. If a slot number cannot be determined then use a path based on FCI address. Examples:
/dev/nvme/by-slot/DriveSlot*
/dev/nvme/by-slot/CardSlot1-ns1 /dev/nvme/by-slot/CardSlot[4-6]-ns1
/dev/nvme/by-addr/0000:81:00.0-ns1

Make sure to include paths for devices that may be added in future.

Include path: /dev/nvme/*/*
Exclude path:

NVMe drives currently available on the selected paths

rac1
/dev/nvme0n1 Size: 1863 GB Slot: CardSlot1-ns1
/dev/nvme1n1 Size: 372 GB Slot: DriveSlot20-ns1

crac2
/dev/nvme0n1 Size: 1863 GB Slot: CardSlot1-ns1
/dev/nvme1n1 Size: 372 GB Slot: DriveSlot20-ns1

crac3
/dev/nvme0n1 Size: 1863 GB Slot: CardSlot1-ns1
FlashGrid Configuration Assistant: Configuring SAS drives

Keep the empty paths if you do not need to share any SAS drives. If you need to share any SAS drives then make sure that the OS drive is excluded or not included.

A non-empty path must match one of following patterns:
/dev/disk/by-path/pci-**-scsi-*
/dev/disk/by-path/pci-**-sas-*
/dev/disk/by-path/pci-**-sata-*

Example:
/dev/disk/by-path/pci-0000:02:00.0-scsi-0:0:24:0

Include path: /dev/disk/by-path/pci-0000:02:00.0-scsi-0+0:2[4-8]:0
Exclude path:

SAS drives currently available on the selected paths

RA01
/dev/sda Size: 465 GB Path: pci-0000:02:00.0-scsi-0:0:24:0
/dev/sdb Size: 465 GB Path: pci-0000:02:00.0-scsi-0:0:25:0

RA02
/dev/sda Size: 465 GB Path: pci-0000:02:00.0-scsi-0:0:24:0
/dev/sdb Size: 465 GB Path: pci-0000:02:00.0-scsi-0:0:25:0

RA03
/dev/sda Size: 465 GB Path: pci-0000:02:00.0-scsi-0:0:24:0

Next  Back  Quit

FlashGrid Configuration Assistant: Configuring Virtual Disks

Keep the default disk paths if using Oracle VM or AWS and all virtual disks (except one OS disk) must be shared by FlashGrid.

Edit the paths if using a different virtual environment or if some virtual disks must be excluded. The exclude path takes precedence over the include path. Make sure that the OS disk and its partitions (typically /dev/xvda*) are excluded or not included.

Include path: /dev/xvd?
Exclude path: /dev/xvda*

Virtual disks currently available on the selected paths

RA01
/dev/xvdf Size: 100 GB Slot: N/A
/dev/xvdg Size: 10 GB Slot: N/A

RA02
/dev/xvdf Size: 100 GB Slot: N/A
/dev/xvdg Size: 10 GB Slot: N/A

Next  Back  Quit
FlashGrid Configuration Assistant: Configuring External iSCSI Disks

Provide information below for connecting to external iSCSI storage server(s).

Note: Only LUN-0 on each target will be used. Multiple LUNs per target are not supported.

<table>
<thead>
<tr>
<th>Server name:</th>
<th>equallogic1</th>
<th>Port:</th>
<th>3260</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP address</td>
<td>10.0.11.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.0.11.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<Add IP>

| Disk name: | mydisk1 | IQN: | iqn.eq.1:t1 |
| Disk name: | mydisk2 | IQN: | iqn.eq.1:t2 |
| Disk name: | mydisk3 | IQN: | iqn.eq.1:t3 |

<Add disk>

<table>
<thead>
<tr>
<th>Server name:</th>
<th>equallogic2</th>
<th>Port:</th>
<th>3260</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP address</td>
<td>10.0.12.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.0.12.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<Add IP>

| Disk name: | mydisk1 | IQN: | iqn.eq.2:t1 |
| Disk name: | mydisk2 | IQN: | iqn.eq.2:t2 |
| Disk name: | mydisk3 | IQN: | iqn.eq.2:t3 |

<Add disk>

<table>
<thead>
<tr>
<th>Server name:</th>
<th></th>
<th>Port:</th>
<th>3260</th>
</tr>
</thead>
</table>

<Add IP>

| Disk name: |          | IQN:  |

<Add disk>

IQN prefix: iqn.eq

- Next
- Back
- Quit

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## FlashGrid Configuration Assistant: Configuring NICs

### Network Interfaces

**Select network interfaces that will be used as storage interconnect**

- **eth0**
- **nic1**
- **nic2**
- **nic3**

**Selected network interfaces:**

- **eth0** 172.31.11.29/20 mtu 9001 up
- **nic3**

[*] Use RDMA (available only on InfiniBand)

---

## FlashGrid Configuration Assistant: Configuring NICs on Quorum Server(s)

### Network Interfaces

**Select network interfaces that will be used as storage interconnect**

- **ib0**
- **ib1**
- **ib4**
- **ib0**
- **ib1**

**Selected network interfaces:**

- **ib0** 192.168.100.1/24 mtu 2044 up
- **ib1** 192.168.101.1/24 mtu 2044 up

[*] Use RDMA (available only on InfiniBand)
FlashGrid Configuration Assistant: Configuring device permissions

Configure permissions for FlashGrid devices that correspond to the Grid Infrastructure owner and administration group.

Owner (e.g. grid or oracle): grid
Group (e.g. asadmin): asadmin

Next  Back  Quit

FlashGrid Configuration Assistant: Configuring Alerts

Select how you would like to be notified of errors:

[*] Syslog:
[*] Email:

Email settings

To: artem@flashgrid.io
From: flashgrid@localhost
Subject prefix: FlashGrid *(common.resource)*
SMTF server: 127.0.0.1
SMTP port: 25
SMTP timeout: 10

Next  Back  Quit

FlashGrid Configuration Assistant: Saving configuration as root

Select how you want to save the new cluster configuration.

Note:
- SAVE & APPLY will not apply changes in the network settings or device permissions until the FlashGrid service is restarted.
- SAVE & RESTART will take all disks offline temporarily. Do NOT select this option if ASM is running!

() SAVE without applying changes or restarting FlashGrid
() SAVE & APPLY changes without restarting FlashGrid
(!) SAVE & RESTART FlashGrid. Do NOT select if ASM is running!

Save  Back  Quit
Example of a cluster status summary after initial configuration

```
[root@rac1 ~]# flashgrid-cluster
FlashGrid 16.11.30.64231 #4a0dbf1b33dfbd26b1714fbb18a19e51e79c1d46
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Cluster verification: OK
Querying nodes: rac02, rac01, quorum ...
```

### Cluster Name: MyCluster

<table>
<thead>
<tr>
<th>Node</th>
<th>Status</th>
<th>ASM_Node</th>
<th>Storage_Node</th>
<th>Quorum_Node</th>
<th>Failgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>rac01</td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>RAC01</td>
</tr>
<tr>
<td>rac02</td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>RAC02</td>
</tr>
<tr>
<td>quorum</td>
<td>Good</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>QUORUM</td>
</tr>
</tbody>
</table>

Example of a node status summary after initial configuration

```
[root@rac1 ~]# flashgrid-node
FlashGrid 16.11.30.64231 #4a0dbf1b33dfbd26b1714fbb18a19e51e79c1d46
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
rac1 node status: Good
```

### Local NICs:

<table>
<thead>
<tr>
<th>Address</th>
<th>Status</th>
<th>Iface</th>
<th>HW</th>
<th>Speed</th>
<th>MTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.168.1.1</td>
<td>Good</td>
<td>eth0</td>
<td>ethernet</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>192.168.100.1</td>
<td>Good</td>
<td>ib0</td>
<td>infiniband</td>
<td>40000</td>
<td></td>
</tr>
<tr>
<td>192.168.101.1</td>
<td>Good</td>
<td>ib1</td>
<td>infiniband</td>
<td>40000</td>
<td></td>
</tr>
</tbody>
</table>

### Local Drives:

<table>
<thead>
<tr>
<th>DriveName</th>
<th>Status</th>
<th>SizeGiB</th>
<th>Slot</th>
<th>WritesUsed</th>
<th>ASMName</th>
<th>ASMSizeGiB</th>
<th>DiskGroup</th>
<th>ASMStatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>rac1.ft441500852p0egn</td>
<td>Good</td>
<td>1863</td>
<td>CardSlot1</td>
<td>0%</td>
<td>RAC1$FT441500852P0EGN</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac1.s1j0nyaf901288</td>
<td>Good</td>
<td>372</td>
<td>DriveSlot20</td>
<td>3%</td>
<td>RAC1$S1J0NYAF901288</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac1.ol7-grid</td>
<td>Good</td>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
<td>RAC1$OL7_GRID</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac1.ol7-grid-tmp</td>
<td>Good</td>
<td>5</td>
<td>N/A</td>
<td>N/A</td>
<td>RAC1$OL7_GRID_TMP</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>quorum.ol7-quorum1</td>
<td>Good</td>
<td>1863</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>quorum.ol7-quorum2</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM2</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>quorum.ol7-quorum3</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM3</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ft5160000fx2p0egn</td>
<td>Good</td>
<td>1863</td>
<td>2</td>
<td>2</td>
<td>RAC2$FT516000FX2P0EGN</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.s1j0nyaf901300</td>
<td>Good</td>
<td>372</td>
<td>2</td>
<td>2</td>
<td>RAC2$S1J0NYAF901300</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ol7-grid</td>
<td>Good</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>RAC2$OL7_GRID</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ol7-grid-tmp</td>
<td>Good</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>RAC2$OL7_GRID_TMP</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### Remote Drives:

<table>
<thead>
<tr>
<th>DriveName</th>
<th>Status</th>
<th>SizeGiB</th>
<th>CfgPaths</th>
<th>ActPaths</th>
<th>ASMName</th>
<th>ASMSizeGiB</th>
<th>DiskGroup</th>
<th>ASMStatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>quorum.ol7-quorum1</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>quorum.ol7-quorum2</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM2</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>quorum.ol7-quorum3</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM3</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ft5160000fx2p0egn</td>
<td>Good</td>
<td>1863</td>
<td>2</td>
<td>2</td>
<td>RAC2$FT516000FX2P0EGN</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.s1j0nyaf901300</td>
<td>Good</td>
<td>372</td>
<td>2</td>
<td>2</td>
<td>RAC2$S1J0NYAF901300</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ol7-grid</td>
<td>Good</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>RAC2$OL7_GRID</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ol7-grid-tmp</td>
<td>Good</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>RAC2$OL7_GRID_TMP</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
11 Installing Grid Infrastructure with GRID Disk Group on FlashGrid Disks

It may be desirable to use FlashGrid disks for the GRID disk group (voting files, OCR, MGMTDB). For example, this may be needed if there is no external storage available that can provide sufficient level of availability.

Grid Infrastructure version 12.1.0.2 installer does not allow configuring a disk group on FlashGrid disks with correct failgroup and disk names. Therefore, additional steps are required when placing GRID disk group on FlashGrid disks.

To create GRID disk group on FlashGrid disks

1. Make sure that you have LVM volumes created for use as GRID disks

2. During Grid Infrastructure configuration configure a disk group for GI files using the temporary GRID disk volumes:
   - Select Normal or High redundancy level for the disk group (do not select External)
   - Add /dev/flashgrid/* to the disk discovery string
   - Include all grid-tmp1 and grid-tmp2 disks from all nodes

3. Before running root.sh script on each node, clear page cache to avoid a bug in AMDU utility:
   
   # echo 1 > /proc/sys/vm/drop_caches

4. Immediately after Grid Infrastructure installation is complete, replace the temporary disks in the disk group with permanent GRID disks using the assistant tool flashgrid-fix-ocr-dg

   Note: Until the disk group created by GI installer is fixed, FlashGrid tools will be showing errors for the disk group and its disks.
12 Creating ASM Disk Groups

**Note:** If storing Grid Infrastructure files (voting files, OCR, MGMTDB) on FlashGrid storage is required then see section 11 for the installation steps.

Use of FlashGrid Disk Group Configuration Assistant is recommended for creating ASM disk groups on FlashGrid disks. This wizard-like tool helps avoid mistakes by automating the following tasks:

- Enforces correct disk group type and compatibility attributes
- Assigns each disk to a correct failgroup based on its physical location
- Checks disk number and size restrictions
- Helps determine correct number of quorum disks
- Offers optimal disk and failgroup repair time depending on the disk group configuration
- Configures preferred read settings

**To create an ASM disk group on FlashGrid disks**

1. If your cluster and disk group configuration requires one or more quorum disks (see section 4.6 Quorum disks) then create the required number of quorum disks. For quorum disks on external storage, except iSCSI disks configured in FlashGrid, add path to the disks to the ASM disk discovery string.
2. Make sure that ASM is running on all nodes that are configured to run ASM.
3. On any ASM node as the Grid Infrastructure owner user run `flashgrid-create-dg`
4. Complete all steps of the FlashGrid Disk Group Configuration Assistant following the instructions on each screen.
5. Run ‘flashgrid-cluster’ command to check status of the newly created disk group.

**FlashGrid Disk Group Configuration Assistant: Disk Group Attributes**
FlashGrid Disk Group Configuration Assistant: Selecting Disks

Select FlashGrid disks that you want to include in the new disk group FLASHG2

<- rac1
  [*] ft441500852p0egn 1863 GiB CardSlot1
<- rac2
  [*] ft816000fx2p0egn 1863 GiB CardSlot1
<- rac3
  [*] ft524500ch2p0egn 1863 GiB CardSlot1

Total capacity available to ASM: 5609 GiB | Capacity after mirroring: 2794 GiB

No errors

FlashGrid Disk Group Configuration Assistant: Selecting Quorum Disks

For the selected disk group configuration the minimum number of quorum disks is 1.

Quorum disks store copies of ASM metadata and must be located independently of the storage nodes. Possible locations are separate Quorum Servers, separate database nodes configured as Quorum Servers, or external iSCSI, FC, or NFS storage (quorum disks for disk groups with ACFS cannot reside on NFS). No user data is stored on the quorum disks. Recommended quorum disk size is 120 MiB.

<- Other non-FlashGrid storage
  [ ] /NFS_DISKS/datal.quorumdisk1 100 MiB !ASM member!
  [*] /NFS_DISKS/datal.quorumdisk2 100 MiB

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FlashGrid Disk Group Configuration Assistant: Setting Disk and FailGroup Repair Time

If needed, customize the disk and failgroup repair times. The disk repair time defines how long ASM waits for an offline disk to become online before it drops the disk and starts rebalancing. The failgroup repair time is similar, but used only when an entire node (failgroup) goes offline.

These parameters are mainly for unexpected disk or node failure scenarios. For planned maintenance the parameters can be overridden in the manual offline command for a disk or a failgroup.

Disk repair time: 1.6h
Failgroup repair time: 240h

FlashGrid Disk Group Configuration Assistant: Allocation Unit Size

If needed, customize the Allocation Unit Size (AU_SIZE) for the disk group.

Allocation Unit Size: 4MB

FlashGrid Disk Group Configuration Assistant: Review Disk Group Summary

We are ready to create the new disk group.

Name: FLASHDG
Type: high
ASM Compatibility: 12.1.0.2
Database Compatibility: 12.1
Disks:
  rac1.ftp44150084p0s0egn 1863 GiB
  rac2.rdb16000tx2p0egn 1863 GiB
  rac3.rdb255000b0p0egn 1863 GiB
Quorum disks:
  /NFS_DISKS/flashdg/quorumdisk1
  /NFS_DISKS/flashdg/quorumdisk2
Total capacity available to ASM: 5599 GiB
Capacity after mirroring: 1863 GiB
Disk repair time: 3.6h
Failgroup repair time: 240h
FlashGrid Disk Group Configuration Assistant: Review SQL

Please review the SQL code for creating the disk group. Press Back if you need to make any changes.

```
CREATE DISKGROUP FLASHDG HIGH REDUNDANCY
    FAILGROUP rac1 DISK '/dev/flashgrid/rac1.ft441500852p0egn' NAME RAC1
    FAILGROUP rac2 DISK '/dev/flashgrid/rac2.ft516000fx2p0egn' NAME RAC2
    FAILGROUP rac3 DISK '/dev/flashgrid/rac3.ft5245000b2p0egn' NAME RAC3
    QUORUM FAILGROUP quorum0 DISK '/NFS_DISKS/flashdg.quorumdisk1' NAME quorumdisk0
    QUORUM FAILGROUP quorum1 DISK '/NFS_DISKS/flashdg.quorumdisk2' NAME quorumdisk1

    ATTRIBUTE 'compatible.asm' = '12.1.0.2', 'compatible.rdms' = '12.1';
    ALTER SYSTEM SET asm_preferred_read_failure_groups='FLASHDG.rac1' SID='+ASM1';
    ALTER SYSTEM SET asm_preferred_read_failure_groups='FLASHDG.rac2' SID='+ASM3';
    ALTER SYSTEM SET asm_preferred_read_failure_groups='FLASHDG.rac3' SID='+ASM2';
    ALTER DISKGROUP FLASHDG SET ATTRIBUTE 'failgroup_repair_time' = '240h';
    ALTER DISKGROUP FLASHDG SET ATTRIBUTE 'disk_repair_time' = '3.6h';
```

FlashGrid Disk Group Configuration Assistant: Finish

```sql
Do you want to create the new disk group now or just save the SQL code in a file?

(*) Create the new disk group and save the SQL code in a file
( ) Only save the SQL code in a file
```

Finish  Back  Quit
Example of a cluster status summary after configuring one disk group

```bash
[root@rac1 ~]# flashgrid-cluster
FlashGrid 16.11.3 0.64231 #4a0dbf1b33d82b26b1714fbb18e51e79c1d46
Cluster verification: OK
Querying nodes: rac02, rac01, quorum ...

Cluster Name: MyCluster

<table>
<thead>
<tr>
<th>Node</th>
<th>Status</th>
<th>ASM_Node</th>
<th>Storage_Node</th>
<th>Quorum_Node</th>
<th>Failgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>rac01</td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>RAC01</td>
</tr>
<tr>
<td>rac02</td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>RAC02</td>
</tr>
<tr>
<td>quorum</td>
<td>Good</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>QUORUM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GroupName</th>
<th>Status</th>
<th>Mounted</th>
<th>Type</th>
<th>TotalMiB</th>
<th>FreeMiB</th>
<th>OfflineDisks</th>
<th>LostDisks</th>
<th>Resync</th>
<th>ReadLocal</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLASHDG</td>
<td>Good</td>
<td>AllNodes</td>
<td>NORMAL</td>
<td>1142984</td>
<td>200243</td>
<td>0</td>
<td>0</td>
<td>No</td>
<td>Enabled</td>
</tr>
<tr>
<td>GRID</td>
<td>Good</td>
<td>AllNodes</td>
<td>NORMAL</td>
<td>20480</td>
<td>17786</td>
<td>0</td>
<td>0</td>
<td>No</td>
<td>Enabled</td>
</tr>
</tbody>
</table>

Example of a node status summary after configuring one disk group

```bash
[root@rac1 ~]# flashgrid-node
FlashGrid 16.11.3 0.64231 #4a0dbf1b33d82b26b1714fbb18e51e79c1d46

rac1 node status: Good

Local NICs:

<table>
<thead>
<tr>
<th>Address</th>
<th>Status</th>
<th>Iface</th>
<th>HW</th>
<th>Speed</th>
<th>MTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.168.1.1</td>
<td>Good</td>
<td>eth0</td>
<td>ethernet</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>192.168.100.1</td>
<td>Good</td>
<td>ib0</td>
<td>infiniband</td>
<td>40000</td>
<td>RDMA</td>
</tr>
<tr>
<td>192.168.101.1</td>
<td>Good</td>
<td>ib1</td>
<td>infiniband</td>
<td>40000</td>
<td>RDMA</td>
</tr>
</tbody>
</table>

Local Drives:

<table>
<thead>
<tr>
<th>DriveName</th>
<th>Status</th>
<th>SizeGiB</th>
<th>Slot</th>
<th>WritesUsed</th>
<th>ASMName</th>
<th>ASMStatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>rac1.ft441500852p3egn</td>
<td>Good</td>
<td>1863</td>
<td>CardSlot1</td>
<td>0%</td>
<td>RAC1$FT441500852P3EGN</td>
<td>N/A</td>
</tr>
<tr>
<td>rac1.s1j0nyaf901288</td>
<td>Good</td>
<td>372</td>
<td>DriveSlot20</td>
<td>3%</td>
<td>RAC1$S1J0NYAF901288</td>
<td>372</td>
</tr>
<tr>
<td>rac1.ol7-grid</td>
<td>Good</td>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
<td>RAC1$OL7_GRID</td>
<td>10</td>
</tr>
<tr>
<td>rac1.ol7-grid-temp</td>
<td>Good</td>
<td>5</td>
<td>N/A</td>
<td>N/A</td>
<td>RAC1$OL7_GRID_TEMP</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Remote Drives:

<table>
<thead>
<tr>
<th>DriveName</th>
<th>Status</th>
<th>SizeGiB</th>
<th>CfgPaths</th>
<th>ActPaths</th>
<th>ASMName</th>
<th>ASMStatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>quorum.ol7-quorum1</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM1</td>
<td>0</td>
</tr>
<tr>
<td>quorum.ol7-quorum2</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM2</td>
<td>0</td>
</tr>
<tr>
<td>quorum.ol7-quorum3</td>
<td>Good</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>QUORUM$OL7_QUORUM3</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.ft5160000fx2p0egn</td>
<td>Good</td>
<td>1863</td>
<td>2</td>
<td>2</td>
<td>RAC2$FT5160000FX2P0EGRN</td>
<td>N/A</td>
</tr>
<tr>
<td>rac2.s1j0nyaf901300</td>
<td>Good</td>
<td>372</td>
<td>2</td>
<td>2</td>
<td>RAC2$S1J0NYAF901300</td>
<td>372</td>
</tr>
<tr>
<td>rac2.ol7-grid</td>
<td>Good</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>RAC2$OL7_GRID</td>
<td>10</td>
</tr>
<tr>
<td>rac2.ol7-grid-temp</td>
<td>Good</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>RAC2$OL7_GRID_TEMP</td>
<td>N/A</td>
</tr>
</tbody>
</table>
```
13 Measuring Performance

DBMS_RESOURCE_MANAGER.CALIBRATE_IO procedure provides an easy way for measuring storage performance including maximum bandwidth, random IOPS, and latency. The CALIBRATE_IO procedure generates I/O through the database stack on actual database files. The test is read-only and it is safe to run it on any existing database. It is also a good tool for directly comparing performance of two storage systems because the CALIBRATE_IO results do not depend on any non-storage factors, such as memory size or the number of CPU cores.

To measure storage performance with CALIBRATE_IO

1. Create or load a database on the corresponding ASM disk group
2. Make sure the total size of the database files is larger than 5 GB per disk. If needed, create an additional large table space / data file.
3. Customize the first parameter in the SQL code below with the number of disks corresponding to your storage setup. Keep the second parameter (max latency) with the minimum allowed value of 10 milliseconds.
4. Connect to the database with sqlplus and run the customized SQL code.
5. Wait for the CALIBRATE_IO to complete. This may take 10 to 30 minutes.

CALIBRATE_IO SQL code

```
SET SERVEROUTPUT ON
DECLARE
  lat INTEGER;
iops INTEGER;
mbps INTEGER;
BEGIN
  DBMS_RESOURCE_MANAGER.CALIBRATE_IO (12, 10, iops, mbps, lat);
  DBMS_OUTPUT.PUT_LINE ('max_iops = ' || iops);
  DBMS_OUTPUT.PUT_LINE ('latency = ' || lat);
  DBMS_OUTPUT.PUT_LINE ('max_mbps = ' || mbps);
END;
/
```

Example of running CALIBRATE_IO on a 3-node cluster with four NVMe SSDs per node
14 Maintenance Tasks

14.1 Rebooting a node

To reboot a converged, storage, or quorum node in a running cluster

1. Make sure there are no other nodes that are in offline or re-syncing state. All disk groups must have zero offline disks and Resync = No.
   
   # flashgrid-cluster

2. Reboot the node using flashgrid-node command. It will gracefully put the corresponding failure group offline.
   
   # flashgrid-node reboot

3. Wait until the node boots up and re-synchronization completes before rebooting or powering off any other node.

   To reboot an compute-only (no storage, no quorum) node in a running cluster
   
   # reboot

14.2 Powering off a node

To power off a converged, storage, or quorum node in a running cluster

1. Make sure there are no other nodes that are in offline or re-syncing state. All disk groups must have zero offline disks and Resync = No.
   
   # flashgrid-cluster

2. Power off the node using flashgrid-node command. It will gracefully put the corresponding failure group offline.
   
   # flashgrid-node poweroff

3. After rebooting the node, wait until the node boots up and re-synchronization completes before rebooting or powering off any other node.

   To power off a compute-only (no storage, no quorum) node in a running cluster
   
   # poweroff

14.3 Shutting down an entire cluster

To shut an entire cluster down

1. Stop Oracle cluster services on all nodes.
   
   # crsctl stop cluster -all

2. Power all nodes off.
14.4 Replacing a failed drive (hot-plug 2.5”)

To replace a failed drive in a running cluster

1. Use ‘flashgrid-cluster drives’ command to determine the following information about the failed drive:
   - FlashGrid name of the drive, e.g. rac2.failedserialnumber
   - ASM name of the drive, e.g. RAC2$FAILEDSERIALNUMBER
   - slot number where the drive is installed
   - whether the ASM disk is online, offline, or dropped (ASMStatus=N/A)
2. Drop the failed disk from the ASM disk group if it has not been dropped yet. Examples:
   a. If the failing ASM disk is still online:
      ```sql
      SQL> alter diskgroup MYDG drop disk RAC2$FAILEDSERIALNUMBER rebalance wait;
      ```
   b. If the failed ASM disk is offline, but has not been dropped by ASM:
      ```sql
      SQL> alter diskgroup MYDG drop disk RAC2$FAILEDSERIALNUMBER force;
      ```
3. Physically remove the failed drive.
4. Plug in a new drive in the same drive slot.
5. Use ‘flashgrid-node’ command to determine its FlashGrid name, e.g. rac2.newserialnumber
6. Add the new drive to the ASM disk group that the failed drive was in. Example:
   ```bash
   $ flashgrid-dg add-disks -G MYDG -d /dev/flashgrid/rac2.newserialnumber
   ```
   If you have to re-add the same drive that was used before or add a different drive that already has ASM metadata on it then you have to add it using the force option ‘-f’ instead of ‘-d’. Example:
   ```bash
   $ flashgrid-dg add-disks -G MYDG -f /dev/flashgrid/rac2.newserialnumber
   ```

14.5 Replacing a failed drive (add-in card)

To replace a failed drive in a running cluster

1. Use ‘flashgrid-cluster drives’ command to determine the following information about the failed drive:
   - FlashGrid name of the drive, e.g. rac2.failedserialnumber
   - ASM name of the drive, e.g. RAC2$FAILEDSERIALNUMBER
   - slot number where the drive is installed
   - whether the ASM disk is online, offline, or dropped (ASMStatus=N/A)
2. Drop the failed disk from the ASM disk group if it has not been dropped yet. Examples:
   a. If the failing ASM disk is still online:
      ```sql
      SQL> alter diskgroup MYDG drop disk RAC2$FAILEDSERIALNUMBER rebalance wait;
      ```
   b. If the failed ASM disk is offline, but has not been dropped by ASM:
      ```sql
      SQL> alter diskgroup MYDG drop disk RAC2$FAILEDSERIALNUMBER force;
      ```
3. Use flashgrid-node utility to power off the node where the failed drive is located:
   ```bash
   # flashgrid-node poweroff
   ```
4. Physically remove the failed drive.
5. Plug in a new drive in the same PCIe slot.
6. Power on the node.
7. Use ‘flashgrid-node’ command to determine FlashGrid name of the new drive, e.g. rac2.newserialnumber
8. Add the new drive to the ASM disk group that the failed drive was in. Example:
$ flashgrid-dg add-disks -G MYDG -d /dev/flashgrid/rac2.newserialnumber

If you have to re-add the same drive that was used before or add a different drive that already has ASM metadata on it then you have to add it using the force option ‘-f’ instead of ‘-d’. Example:

$ flashgrid-dg add-disks -G MYDG -f /dev/flashgrid/rac2.newserialnumber

14.6 Adding drives

To add new hot-plug drives in a running cluster

1. Plug in new drives.
2. Use ‘flashgrid-cluster drives’ command to determine FlashGrid names of the drives, e.g. rac2.newserialnumber
3. Run ‘flashgrid-create-dg’ to create a new disk group with the new drives or add the new drives to the ASM disk group. Example:

   $ flashgrid-dg add-disks -G MYDG -d /dev/flashgrid/rac1.newserialnumber1 /dev/flashgrid/rac2.newserialnumber2

14.7 Removing drives

To remove hot-plug drives from a running cluster

1. Use ‘flashgrid-cluster drives’ command to determine the following information about the drives that will be removed:
   - ASM name of the drive, e.g. RAC2$SERIALNUMBER
   - Slot numbers where the drives are installed
2. If the drives are members of an ASM disk group then drop the drives from the disk group. Example:

   SQL> alter diskgroup MYDG
drop disk RAC1$SERIALNUMBER1
drop disk RAC2$SERIALNUMBER2
rebalance wait;

3. Prepare the drives for removal. Example:

   [root@rac1 ~] # flashgrid-node stop-target /dev/flashgrid/racl.serialnumber1
   [root@rac2 ~] # flashgrid-node stop-target /dev/flashgrid/rac2.serialnumber2

4. Physically remove the drives.

14.8 Replacing a failed server

To replace a failed server with new hardware in a running cluster

1. Move all drives from the failed server to a new server. Make sure to install the drive in the same slots where they were installed before.
2. Make sure the host name or alias of the new server is the same as it was on the failed server.
3. On any other node of the cluster run flashgrid-ca
4. Select ‘Modify existing configuration’ and press Next
5. Press Next
6. Select ‘SAVE & APPLY changes without restarting FlashGrid’
7. Press Save
14.9 Adding a node to a cluster

To add a new node to an existing FlashGrid cluster

1. Prepare the new node for adding it to the cluster. See the following sections of this guide:
   - Installing and Configuring OS
   - Installing FlashGrid Software
   - Installing RDMA Drivers and Utilities
   - Configuring Storage Network
   - Creating LVM Volumes for Quorum and GRID Disks
2. Run flashgrid-ca on any node that is already a member of the cluster
3. Select ‘Modify existing configuration’ and press Next
4. Select ‘Cluster nodes’ and press Next
5. Enter short host name for the node and select its role from the scroll down list
6. Press Next
7. Select ‘SAVE & APPLY changes without restarting FlashGrid’
8. Press Save

14.10 Removing a node from a cluster

To remove a node from a FlashGrid cluster

1. Stop FlashGrid services on the node that you want to remove
   
   # flashgrid-node stop
2. Run flashgrid-ca on any node of the cluster
3. Select ‘Modify existing configuration’ and press Next
4. Select ‘Cluster nodes’ and press Next
5. Enter short host name for the node and select its role from the scroll down list
6. Press Next
7. Select ‘SAVE & APPLY changes without restarting FlashGrid’
8. Press Save

14.11 Updating FlashGrid software

The following procedure applies to minor updates. Minor updates are those that have the same first two numbers in the version number, for example, from 16.9.30 to 16.9.40. However, update from 16.7 to 16.11 is considered major and may require a different procedure. Contact FlashGrid support for assistance if you need to do a major version update.

To update FlashGrid software on a running cluster repeat the following steps on each node, one node at a time

1. If the node has ASM running then stop Oracle CRS:
   
   # crsctl stop crs
2. Stop the FlashGrid services:
   
   # flashgrid-node stop
3. Update the FlashGrid RPM using yum or rpm tool
4. Start the FlashGrid service
   
   # flashgrid-node start
5. If the node has ASM installed on it then start Oracle CRS:

   # crsctl start crs -wait

4. Wait until all disks are back online and resyncing operations complete on all disk groups before updating the next node. All disk groups must have zero offline disks and Resync = No.

   # flashgrid-cluster

14.12 Updating Linux kernel

To update Linux kernel on a running cluster repeat the following steps on each node, one node at a time

1. If this is major kernel version update and if using InfiniBand or RoCE then verify that the installed RDMA drivers are compatible with the new kernel version. Minor kernel updates normally do not require updating the RDMA drivers.
2. Install the new kernel
3. Follow the steps for rebooting a node
15 FlashGrid Tools and Commands

15.1 flashgrid-ca

FlashGrid Configuration Assistant helps configure a new FlashGrid cluster in a few easy steps.

Usage: flashgrid-ca [-h] [-f]

Options:
- `-h` Show this help message and exit
- `-f` Ignore terminal size check

15.2 flashgrid-fix-grid-dg-ca

Assistant tool for replacing temporary disks with permanent disks after GI installation.

Usage: flashgrid-fix-grid-dg-ca [-h] [-f]

Options:
- `-h` Show this help message and exit
- `-f` Ignore terminal size check

15.3 flashgrid-create-dg

FlashGrid Disk Group Configuration Assistant helps configure ASM disk groups with FlashGrid disks in a few easy steps.

Usage: flashgrid-create-dg [-h] [-f]

Options:
- `-h` Show this help message and exit
- `-f` Ignore terminal size check

15.4 flashgrid-cluster

CLI tool for cluster-level monitoring and management of all cluster nodes and disk groups.

Usage: flashgrid-cluster [command]

Commands:
- `show` Show cluster status (default if no command provided)
- `drives` List all drives in the cluster
- `net` List all NICs in the cluster
- `verify` Verify FlashGrid cluster configuration
- `deploy-config` Deploy configuration from /etc/flashgrid.cfg on the local node to all nodes
- `fix-readlocal` Fix Read-Local settings on all ASM instances
- `fix-disk-names` Generate ASM SQL for fixing ASM disk names if any are invalid
strict-read-local-enable
Enable strict Read-Local mode. Database auto-start is delayed until all local disks are online.

strict-read-local-disable
Disable strict Read-Local mode and restore original database startup dependencies.

strict-read-local-show
For all databases show whether strict Read-Local mode is enabled or disabled.

help
Show this help message and exit

15.5 flashgrid-node
CLI tool for monitoring and management of the local node.
Usage: flashgrid-node [-f] [command]
Commands:
  show Show node details (default if no command provided)
  test-alerts Send test email alert.
  collect-diags Create diagnostics archive file for the local node.
  stop Gracefully offline the local failgroup and stop flashgrid services. '-f' option forces stop even if graceful offline fails.
  start Start flashgrid service and online local disks in ASM
  reboot Gracefully offline the local failgroup and reboot the node. '-f' option forces reboot even if graceful offline fails.
  poweroff Gracefully offline the local failgroup and power the node off. '-f' option forces reboot even if graceful offline fails.
  offline Gracefully offline the local failgroup.
  online Bring the local failgroup online for each mounted disk group.
  stop-waiting Stop waiting for all storage nodes and allow Oracle services to start.
  stop-target Gracefully offline the corresponding disk in ASM and stop the target. '-f' option forces target target stop even if graceful offline fails.
  reload-config Reload flashgrid config without restart. Note that network configuration is not reloaded.
  restart-services Gracefully offline the local failgroup, restart flashgrid service and online local disks in ASM. '-f' option forces restart even if graceful offline fails.
**restart-targets**  Gracefully offline the local failgroup, restart flashgrid targets service, and online local disks in ASM. '-f' option forces target service restart even if graceful offline fails.

**restart-initiators**  If there are no mounted ASM disk groups using FlashGrid disks then restart flashgrid initiators service. '-f' option forces restart even if there are mounted groups.

**restart-asm-connector**  Restart the FlashGrid ASM connector service.

**restart-cluster-connector**  Restart FlashGrid cluster connector service.

**verify-config**  Verify validity of the local config file /etc/flashgrid.cfg

**shell**  Start shell (for internal and tech support use).

**asm-state**  Show ASM state in JSON format (for internal use).

**help**  Show this help message and exit

### 15.6 flashgrid-dg

CLI tool for monitoring and management of individual disk groups.

**Usage:** flashgrid-dg [command]

**Commands:**

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>list</td>
<td>List all FlashGrid disk groups (default if no command provided).</td>
</tr>
<tr>
<td>show</td>
<td>Show details of the disk group.</td>
</tr>
<tr>
<td>create</td>
<td>Create a new ASM disk group.</td>
</tr>
<tr>
<td>add-disks</td>
<td>Add disks to the disk group.</td>
</tr>
<tr>
<td>replace-disk</td>
<td>Replace a disk with a new one.</td>
</tr>
<tr>
<td>help</td>
<td>Show this help message and exit</td>
</tr>
</tbody>
</table>
16 Troubleshooting

The following troubleshooting steps are recommended in case of any issues with FlashGrid cluster configuration or operation:

1. Check status of all FlashGrid nodes, network, and disk groups by running `flashgrid-cluster` on any node.
2. If network verification fails then run `flashgrid-cluster verify` to get more detailed information.
3. On any node that has a Warning, Critical, or Inaccessible status:
   a. Check whether the FlashGrid service is active:
      # systemctl status flashgrid
   b. Check status of NICs, local disks, and remote disks:
      # flashgrid-node
   c. Check that the configuration has no errors:
      # flashgrid-node verify-config
4. Check detailed status information of various FlashGrid components on the affected nodes:
   a. Run `flashgrid-node shell`
   b. Navigate through the tree of FlashGrid objects using `ls` and `cd` commands
   c. For example, display details of all physical drives: `ls /hw`
5. Check FlashGrid logs in the following log files on the affected nodes:
   a. /opt/flashgrid/log/fgridd-all.log
   b. /opt/flashgrid/log/fgridd-error.log
   c. /opt/flashgrid/log/iamback-all.log
   d. /opt/flashgrid/log/iamback-error.log

17 Contacting FlashGrid Technical Support

If you need help with troubleshooting an issue on an existing FlashGrid cluster please collect diagnostic data by running `flashgrid-node collect-diags` command on each node and email it to FlashGrid technical support along with a summary of the issue.

Users with technical support subscription: support@flashgrid.io

New users: info@flashgrid.io

Phone: +1-650-641-2421