100Gb Backup Solution

Oracle Exadata Database Machine X8M with Oracle ZFS Storage Appliance ZS7-2

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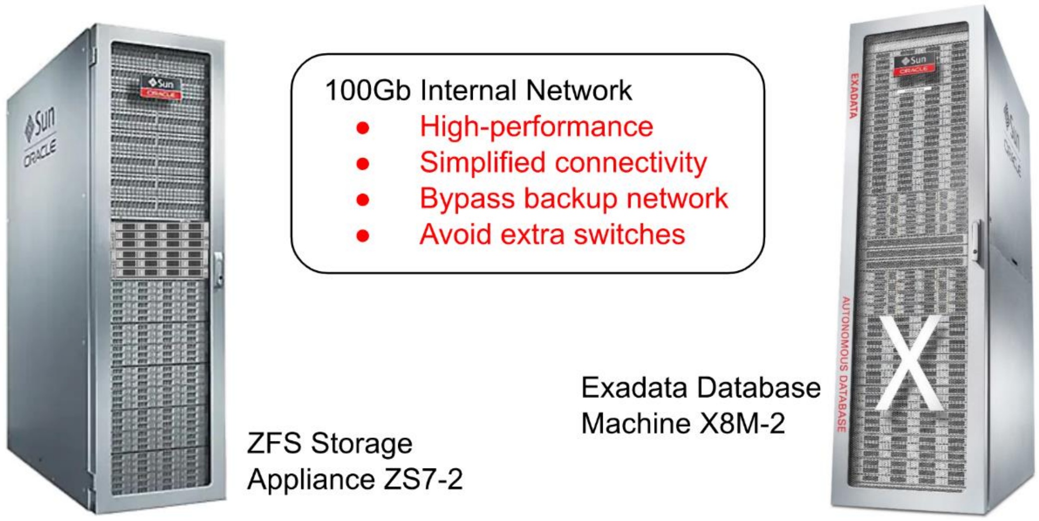
EXECUTIVE OVERVIEW

The Oracle Exadata X8M generation introduces a new and improved networking infrastructure built on high-speed, low latency network fabric optimized for RDMA over Converged Ethernet (RoCE). This paper focuses on configuration best practices when using an Oracle ZS7 Storage Appliance to provide data protection services for a RoCE based Oracle Exadata Database Machine.

Protecting the mission-critical data that resides on Oracle Exadata Database Machine (Oracle Exadata) is a top priority. The Oracle ZFS Storage Appliance is ideally suited for this task due to superior performance, enhanced reliability, extreme network bandwidth, powerful features, simplified management, and cost-efficient configurations.

The Oracle ZS7 Storage Appliance is the first platform to offer a 100Gb backup solution by directly connecting to the Exadata RoCE network fabric at 100Gb. This bypasses the traditional backup network and provides a local backup option that is optimized for performance and simplicity. 100Gb Ethernet adapters are installed in the ZS7-2 controllers and backups are run from the Exadata database servers using standard TCP.



100Gb Internal Network

- High-performance
- Simplified connectivity
- Bypass backup network
- Avoid extra switches

Figure 1. Oracle Exadata X8M and Oracle ZFS Storage Appliance ZS7-2 100Gb backup solution overview

Directly connecting to the Exadata RoCE network eliminates the need to acquire and manage dedicated switches. This provides superior ROI and tighter integration. Oracle Exadata RoCE network switches are also managed as part of the Engineered System's hardware and software infrastructure, including monitoring, maintenance and security updates. The solution therefore does not require additional knowledge or skillset to maintain.

The following graph shows maximum sustainable Oracle Recovery Manager (RMAN) rates that were achieved with a quarter-rack X8M Extreme Flash attached to a ZS7-2 high-end with 4 high capacity disk shelves. The graph shows rates for an Oracle Database backing up to either a single ZS7 controller or both (dual) controllers. Physical throughput rates were measured at the network level for RMAN workloads between Oracle Exadata and Oracle ZFS Storage Appliance systems.

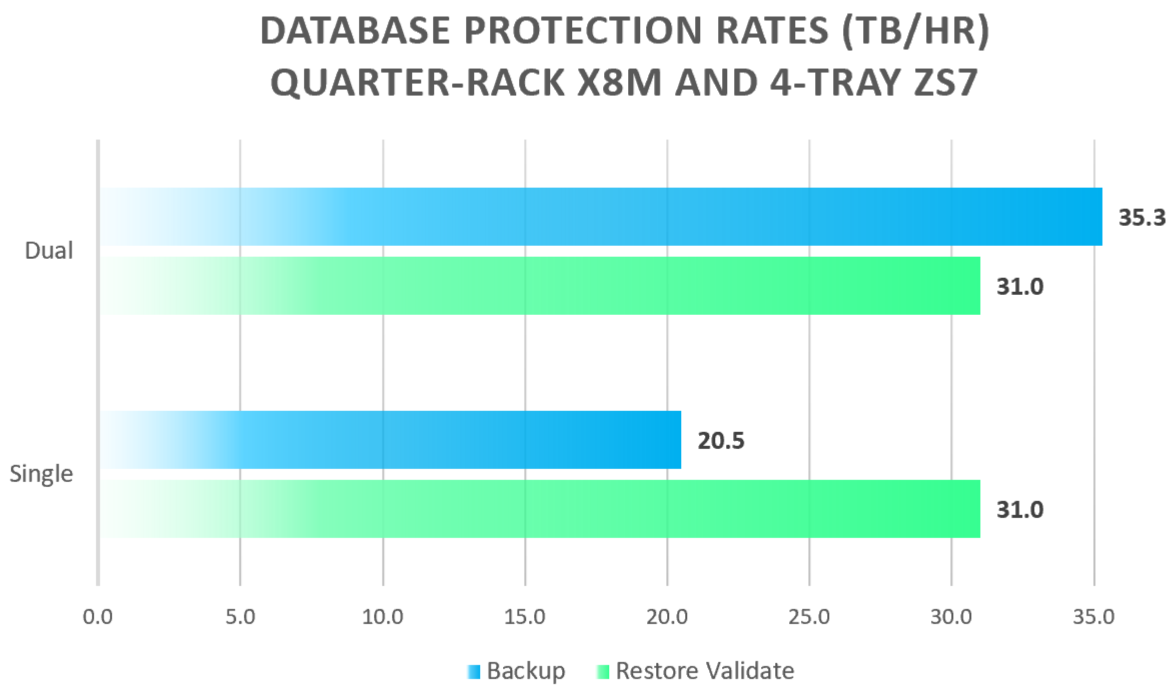


Figure 2. RMAN rates achieved with quarter-rack X8M and 4-shelf ZS7-2 using 100Gb direct attach backup solution. Includes database backup rates to a single ZS7-2 controller and both (dual) controllers.

A backup rate of **35.3 TB/hr** for this X8M quarter-rack/ZS7-2 configuration was recorded in the lab environment using a double parity storage profile. These are complete, real-world results using Oracle Database 19*c* and an online transactional processing (OLTP) database that was populated with sample customer data in a sales order-entry schema. Advanced Row Compression, an Oracle Database feature, was used at the database level to align with best-practice recommendations for customers that are running OLTP workloads. These throughput rates were not obtained using a database or input/output (I/O) generator test tool, which can be misleading. Also, they were not projected based on low-level system benchmarks.

The performance data collected for this document was measured using level 0 backup operations for an Oracle Database with no concurrent front-end transactional load. When testing the same configuration with a moderate OLTP transactional workload running concurrently with the backup, a rate of **32.0 TB/hr** was recorded. The database workload with a concurrent RMAN backup load still achieved **90.9%** of the performance recorded on an idle system. When accounting for database-level compression or incremental backup strategies, effective backup rates that are much higher than the physical rates documented here are routinely observed.

High performance is an important consideration when choosing a solution to protect Oracle Exadata. The following technologies make it possible for Oracle ZFS Storage Appliance systems to achieve these backup and restore rates:

» **Oracle Recovery Manager Integration** – Oracle Recovery Manager (Oracle RMAN) is a highly parallelized application that resides within Oracle Database and optimizes backup and recovery operations. Oracle ZFS Storage Appliance systems are designed to integrate with Oracle RMAN by utilizing up to 3,000 concurrent threads that distribute I/O across many channels spread across multiple controllers. This improves performance dramatically with sequential large block streaming I/O workloads that are typical for most backup and restore situations.

» **Oracle Database's Direct NFS Client feature** – The optimized Direct NFS Client feature is an aggressive implementation that allocates individual TCP connections for each Oracle Database process, in addition to reducing CPU and memory overhead, by bypassing the operating system and writing buffers directly to user space.

- **1 MB Record Sizes** – Oracle ZFS Storage Appliance systems enable larger 1 MB record sizes. This reduces the number of input/output operations per second (IOPS) that are required to disk, preserves the I/O size from Oracle RMAN buffers to storage, and improves performance of large-block sequential operations.
- **Hybrid Storage Pools** – Oracle ZFS Storage Appliance systems have an innovative Hybrid Storage Pool (HSP) architecture that utilizes dynamic storage tiers across memory, flash, and disk. The effective use of dynamic random-access memory (DRAM) and enterprise-class software specifically engineered for multilevel storage is a key component that facilitates the superior performance of Oracle ZFS Storage Appliance systems.

The performance benefits of the Oracle ZFS Storage Appliance are well documented and independently verified. Oracle periodically publishes Storage Performance Council's SPC-1 and SPC-2 benchmark results, as well as Standard Performance Evaluation Corporation's SPEC SFS benchmark results to demonstrate performance results for the Oracle ZFS Storage Appliance. Combine this with the powerful features, simplified management, and Oracle-on-Oracle integrations, and it is easy to see why these systems are a compelling solution for protecting mission-critical data on Oracle Exadata.

INTRODUCTION

This document focuses on networking guidelines for setting up a 100Gb-attached local backup solution with Oracle ZFS Storage Appliance ZS7-2 for optimal backup and recovery of Oracle Databases running on an Oracle Exadata X8M Database Machine. Selecting the right backup strategy, understanding encryption options and when to deploy a deduplication solution are all important considerations. Guidelines to help understand and make these deployment decisions are provided in My Oracle Support document 2087231.1 "Guidelines when Using ZFS Storage in an Exadata Environment." This solution brief illustrates the 100Gb networking guidelines by utilizing a reference architecture with a standard RMAN backup strategy and no encryption or deduplication requirements.

This paper addresses the following topics:

- Configuring the 100Gb network
- Configuring the Oracle ZFS Storage Appliance
- Configuring the Oracle Exadata X8M

Database, system, and storage administrators are faced with a common dilemma when it comes to backup and recovery of Oracle Database instances—how to back up more data, more often, in less time, and within the same budget. Moreover, practical challenges associated with real-world outages mandate that data protection systems be simple and reliable to ensure smooth operation under compromised conditions. The Oracle ZFS Storage Appliance helps administrators meet these challenges by providing cost-effective and high-bandwidth storage systems that combine the simplicity of the NFS protocol with ZFS-enhanced disk reliability. Through Oracle ZFS Storage Appliance technology, administrators can reduce the capital and operational costs associated with data protection while maintaining strict service-level agreements with end customers.

CONFIGURING THE 100Gb NETWORK

This section documents specific cabling guidelines and networking best practices to support a high performance and highly available data protection solution using direct-attached 100Gb interfaces.

The Oracle ZFS Storage Appliance leverages a dual-port 100Gb Ethernet adapter in each ZS7-2 controller to directly connect to the Oracle Exadata X8M internal leaf switches. These are Cisco 9336C-FX2-OR 100Gb Ethernet switches.

There are a limited number of ports available on the Exadata X8M switches. Ports 4 through 33 are reserved for the RoCE internal network and are not to be used. These ports should be reserved even in a partial rack configuration to enable the option of future expansion. This solution uses ports outside of the dedicated RoCE range. This architecture currently supports X8M leaf switches with standard golden configuration templates for single-rack or multi-rack. Support for RoCE secure fabric isolation switch configurations with multiple VLANs is planned for a future release.

Port 1 of the 100Gb adapter in each Oracle ZS7-2 controller connects to the lower Exadata leaf switch (Switch 1). Port 2 connects to the upper Exadata leaf switch (Switch 2). Controller 1 connects to switch port 3 while controller 2 connects to port 35. The configuring IO cards section of this document provides more details on the installation and setup of network cards on the storage.

Figure 3 depicts the network cabling diagram for the 100Gb local backup solution. This configuration provides a high-performance fault-tolerant architecture for local backup using Oracle ZFS Storage Appliance.

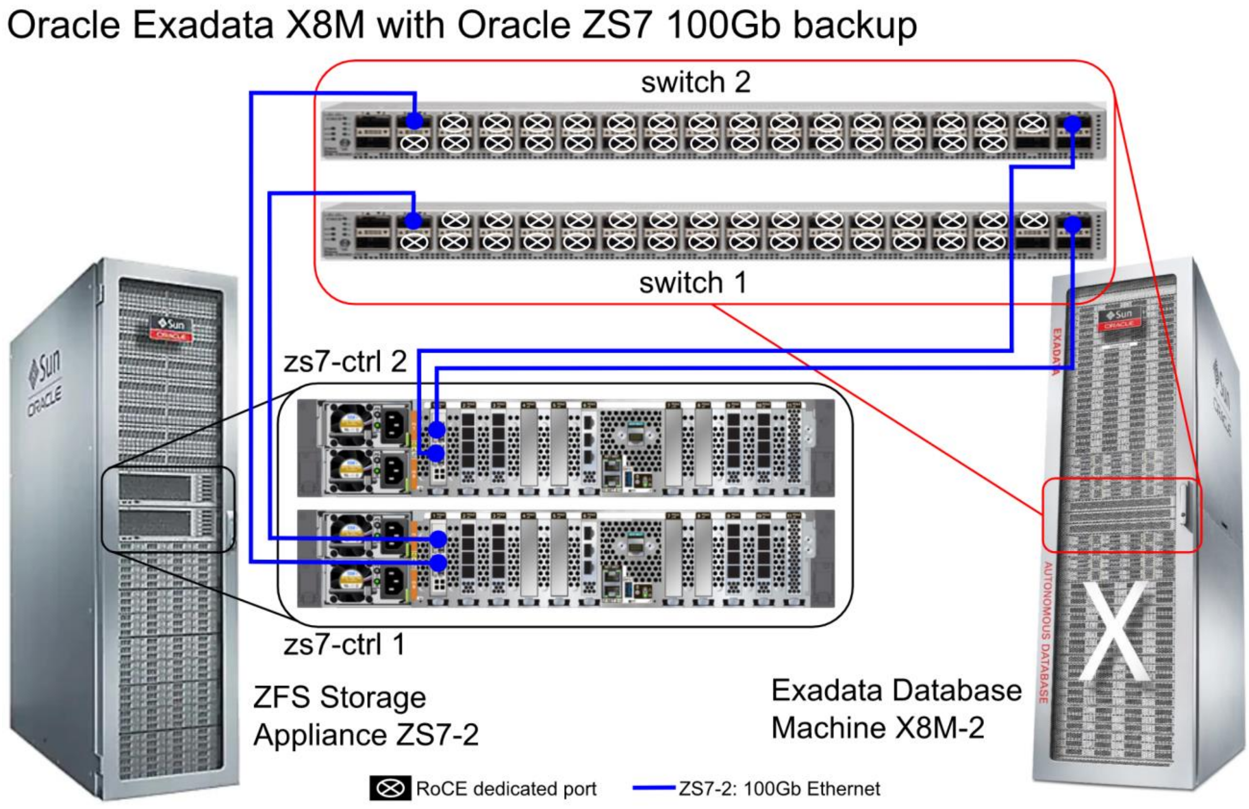

Oracle Exadata X8M with Oracle ZS7 100Gb backup
switch 2
switch 1
zs7-ctrl 2
zs7-ctrl 1
ZFS Storage Appliance ZS7-2
Exadata Database Machine X8M-2
EXADATA
AUTONOMOUS DATABASE
⊗ RoCE dedicated port
ZS7-2: 100Gb Ethernet

Figure 3. Network diagram for 100Gb local backup solution.

Ports 4 through 33 are part of the internal RoCE network fabric and remain unchanged. Ports 3 and 35 are used to connect 100Gb interfaces of the Oracle ZFS Storage Appliance. The following table documents the port mapping details of this network solution.

TABLE 1. 100GB BACKUP NETWORK PORT MAPPING EXADATA LEAF SWITCHES

Group	Switch 1	Switch 2	Comments
Eth1/3	Controller 1 PCIe 1 port 1	Controller 1 PCIe 1 port 2	ZS7-2 controller 1 100Gb links
Eth1/4-33	Database and Storage Servers, Inter-switch links	Database and Storage Servers, Inter-switch links	Range dedicated for internal RoCE network fabric
Eth1/34			RoCE port in certain X8M-8 configurations

Eth1/35	Controller 2 PCIe 1 port 1	Controller 2 PCIe 1 port 2	ZS7-2 controller 2 100Gb links

Switch Configuration Best Practices

VLAN

The Oracle ZS7-2 100Gb ports should be configured to match the Virtual Local Area Network (VLAN) ID used for the RoCE network fabric during the initial installation of the Exadata deployment. If this VLAN ID is unavailable, it is possible to change the RoCE VLAN ID during Exadata deployment to another ID in the range of 2744-3967. In most environments this will be 3888.

MTU

The Maximum Transmission Unit (MTU) setting helps determine the largest packet size that can be communicated over the network. The default MTU is 1500 bytes. Larger MTU sizes reduce the level of IP fragmentation and allow for more efficient processing of large streaming workloads with lower CPU overhead.

The Exadata Database Server RoCE interfaces are optimized to use an MTU of 2300. The Oracle ZS7-2 100Gb ports should be configured to match the client MTU size of 2300.

LACP

Link Aggregation Control Protocol (LACP) is not necessary in this solution because the Database Server RoCE ports use active path management. The Oracle ZS7-2 100Gb Ethernet ports will provide redundancy by using IP Multi-Pathing (IPMP) groups. LACP should not be configured on the switches.

Speed and Duplex

The Oracle Exadata X8M Database Server RoCE ports have auto negotiation disabled, therefore the connecting 100Gb ZS7-2 ports must be configured to match. To match the RoCE ports it is required to disable auto negotiation, set speed to 100000 and set duplex to full.

Golden Configuration Templates

Oracle Exadata X8M leaf switches are configured with a template during the deployment process. For more information on RoCE network fabric switch configurations refer to Oracle Exadata Installation Documentation.

This architecture currently supports standard single-rack switch configurations and standard multi-rack switch configurations. Support for secure RDMA fabric isolation switch configurations is planned for a future release.

Switch Configuration Steps

This section provides an example on the steps necessary to configure the Oracle Exadata X8M leaf switches for 100Gb local backup. The example provided here assumes the default VLAN ID of 3888 is in use for the RoCE network fabric.

Switch 1

Login to switch1 as the admin user. Set default settings on ports 3 and 35 to cleanup any stale configuration before proceeding.

```
switch1# conf t
switch1(config)# default int Eth1/3
switch1(config)# default int Eth1/35
```

Modify ports 3 and 35 to configure ZS7-2 100Gb connections on switch1.

```
switch1(config)# int Eth1/3
switch1(config-if)# description ZS72-1_100gb_p1
switch1(config-if)# switchport access vlan 3888
switch1(config-if)# mtu 2300
switch1(config-if)# speed 100000
switch1(config-if)# no negotiate auto
switch1(config-if)# duplex full
switch1(config-if)# priority-flow-control mode off
switch1(config-if)# spanning-tree bpduguard enable
switch1(config-if)# spanning-tree port type edge
```

```
switch1(config-if)# no cdp enable
switch1(config-if)# no shut
switch1(config-if)# ex
switch1(config)# int Eth1/35
switch1(config-if)# description ZS72-2_100gb_p1
switch1(config-if)# switchport access vlan 3888
switch1(config-if)# mtu 2300
switch1(config-if)# speed 100000
switch1(config-if)# no negotiate auto
switch1(config-if)# duplex full
switch1(config-if)# priority-flow-control mode off
switch1(config-if)# spanning-tree bpduguard enable
switch1(config-if)# spanning-tree port type edge
switch1(config-if)# no cdp enable
switch1(config-if)# no shut
switch1(config-if)# ex
```

Exit the config prompt and save the configuration on switch1.

```
switch1(config)# end
switch1# copy running-config startup-config
```

Switch 2

Login to switch2 as the admin user. Set default settings on ports 3 and 35 to cleanup any stale configuration before proceeding.

```
switch2# conf t
switch2(config)# default int Eth1/3
switch2(config)# default int Eth1/35
```

Modify ports 3 and 35 to configure ZS7-2 100Gb connections on switch2.

```
switch2(config)# int Eth1/3
switch2(config-if)# description ZS72-1_100gb_p2
switch2(config-if)# switchport access vlan 3888
switch2(config-if)# mtu 2300
switch2(config-if)# speed 100000
switch2(config-if)# no negotiate auto
switch2(config-if)# duplex full
switch2(config-if)# priority-flow-control mode off
switch2(config-if)# spanning-tree bpduguard enable
switch2(config-if)# spanning-tree port type edge
switch2(config-if)# no cdp enable
switch2(config-if)# no shut
switch2(config-if)# ex
switch2(config)# int Eth1/35
switch2(config-if)# description ZS72-2_100gb_p2
switch2(config-if)# switchport access vlan 3888
switch2(config-if)# mtu 2300
switch2(config-if)# speed 100000
switch2(config-if)# no negotiate auto
switch2(config-if)# duplex full
switch2(config-if)# priority-flow-control mode off
switch2(config-if)# spanning-tree bpduguard enable
switch2(config-if)# spanning-tree port type edge
switch2(config-if)# no cdp enable
switch2(config-if)# no shut
switch2(config-if)# ex
```

Exit the config prompt and save the configuration on switch2.

```
switch2(config)# end
switch2# copy running-config startup-config
```

Backup for Multiple Environments

The Oracle ZFS Storage Appliance ZS7-2 can serve as a 100Gb backup target for a single-rack or multi-rack X8M environment. However, the ZS7-2 controllers can each support only one 100Gb Ethernet adapter. This prevents the system from serving as the backup target for multiple X8M environments. For use cases where a single Oracle ZFS Storage Appliance must provide data protection for multiple Oracle Exadata environments please refer to the top of rack switched 25Gb or 40Gb solutions provided in Exadata X8M Backup with ZFS Storage Appliance.

CONFIGURING THE ORACLE ZFS STORAGE APPLIANCE

This section provides best practices for optimizing an Oracle ZFS Storage Appliance system to provide Oracle Database protection in an Oracle Exadata X8M environment with a standard RMAN backup strategy.

Choosing a Controller

Oracle ZFS Storage Appliance systems are available in two models: Oracle ZFS Storage ZS7-2 mid-range and Oracle ZFS Storage ZS7-2 High-End. The following table provides details for each model.

TABLE 2. ORACLE ZFS STORAGE APPLIANCE DETAILS

Features	Oracle ZFS Storage ZS7-2 Mid-Range	Oracle ZFS Storage ZS7-2 High-End
CPU Cores	72	96
DRAM	1 or 2 TB	3 TB
Maximum Read-Optimized Flash	Up to 737 TB	Up to 1.4 PB
Maximum Write-Optimized Flash	Up to 18.6 TB	Up to 37.5 TB
Raw Storage Capacity	24 TB to 8 PB Scalability	24 TB to 16 PB Scalability
High-Availability Cluster Option	Yes	Yes
Focus	Medium-sized	Scalability

Please refer to oracle.com/storage/nas/index.html for the latest Oracle ZFS Storage Appliance model specifications.

Oracle ZFS Storage ZS7-2 High-End is a flagship product that offers maximum levels of scalability, CPU, and DRAM. This is a highly scalable platform that can support up to 16 PB of raw storage capacity.

Oracle ZFS Storage ZS7-2 Mid-Range is a cost-efficient model that can still achieve high levels of throughput and redundancy but does not provide the same level of scalability that the high-end model does.

A ZS7-2 high-end model is recommended for Exadata backup.

Choosing the Correct Disk Shelves

Oracle ZFS Storage Appliance systems include a configurable number of disk shelves. **A standard RMAN backup use case should use high-capacity (DE3-24C) disk shelves.** Oracle Storage Drive Enclosure DE3-24C features high-capacity 14 TB disks. Each disk shelf contains 24 disks and can be configured with optional write-optimized flash. (Up to four disks per disk shelf can be replaced with solid-state drive [SSD] write-flash accelerators.) Oracle ZFS Storage ZS7-2 can be customized based on disk shelf and write-optimized flash requirements. **A minimum of 3 disk shelves should be included in the configuration to provide full redundancy.** This will allow for a No Single Point of Failure (NSPF) storage configuration that can tolerate the loss of a disk shelf.

For standard RMAN backup use cases it is recommended to include write-flash accelerators at a minimum ratio of 4 per every 4 disk shelves. For example, an 8 disk shelf configuration would include 6 shelves of 24 14 TB drives and 2 shelves of 20 14 TB drives and 4 write-flash accelerators. If standard RMAN backup is the primary use case but the ZS7-2 will also be handling other use cases that generate a significant number of synchronous writes, then it is recommended to include write-flash accelerators at a minimum ratio of 4 per every 2 disk shelves.

Choosing a Storage Profile

When a storage profile is selected to protect Oracle Exadata, mirrored, single-parity, and double-parity profiles are all worthy of consideration. The following table provides a comparison of the storage profiles. **For a standard RMAN backup use case it is recommended to use a double parity storage profile.**

TABLE 3. STORAGE PROFILE COMPARISON

Profile	Usable Capacity	Advantages	Negatives
Mirrored	42.2%	Restore performance	Costly

		Maximum protection Maximum flexibility	
Single Parity	69.3%	Backup performance Moderate flexibility	Limited redundancy
Double Parity	76.7%	Streaming performance Most efficient	Limited IOPS

Note: Useable capacity accounts for raw capacity lost due to parity, spares, and file system overhead, as well as small amounts of space lost on each disk due to operating system (OS) overhead, drive manufacturer overhead, and scratch space reservations. This will vary slightly depending on the size of the storage pool; this example assumes a configuration with four disk shelves.

Double Parity

Double parity provides the best usable capacity and performs as well as single parity for large streaming I/O, which is typical for standard Oracle RMAN workloads. It accomplishes this by utilizing a wide stripe width. The width varies at the time of storage pool creation depending on the number of disks in the configuration, but it ranges up to 14 disks. As a result, the number of virtual devices (vdevs) in a double-parity storage pool is far fewer than with mirrored or single parity profiles. The ability to handle IOPS-intensive workloads is severely diminished.

Double parity is recommended when Oracle ZFS Storage Appliance systems are 100 percent dedicated to large sequential workloads, such as traditional Oracle RMAN backup and restore workloads. It is not advisable for use cases such as cloning for DevTest provisioning or utilizing an incrementally updated backup strategy. Mirrored or single-parity profiles are more flexible for handling additional use cases that might result in heavier disk IOPS with lower latencies. Figure 4 reflects raw disk capacity distribution for different storage profiles.

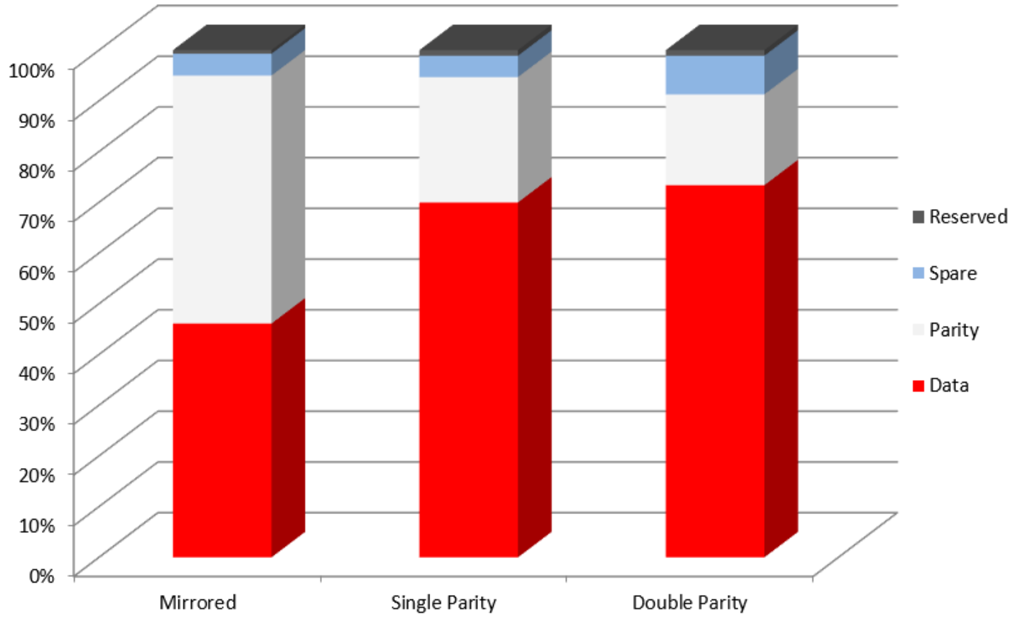


Figure 4. Raw disk capacity distribution

Configuring the Storage Pools

In most situations it is recommended to configure two storage pools with one primary on each controller. This allows for an active/active backup environment that leverages the CPU, memory and networking resources of both ZS7 controllers. This provides better performance and Return on Investment (ROI).

In situations where strict performance Service Level Agreements (SLA)s must be maintained even during failure scenarios it may be recommended to configure a single storage pool and enable an active/standby backup environment where one of the ZS7 controllers will sit idle waiting to take over for the active controller.

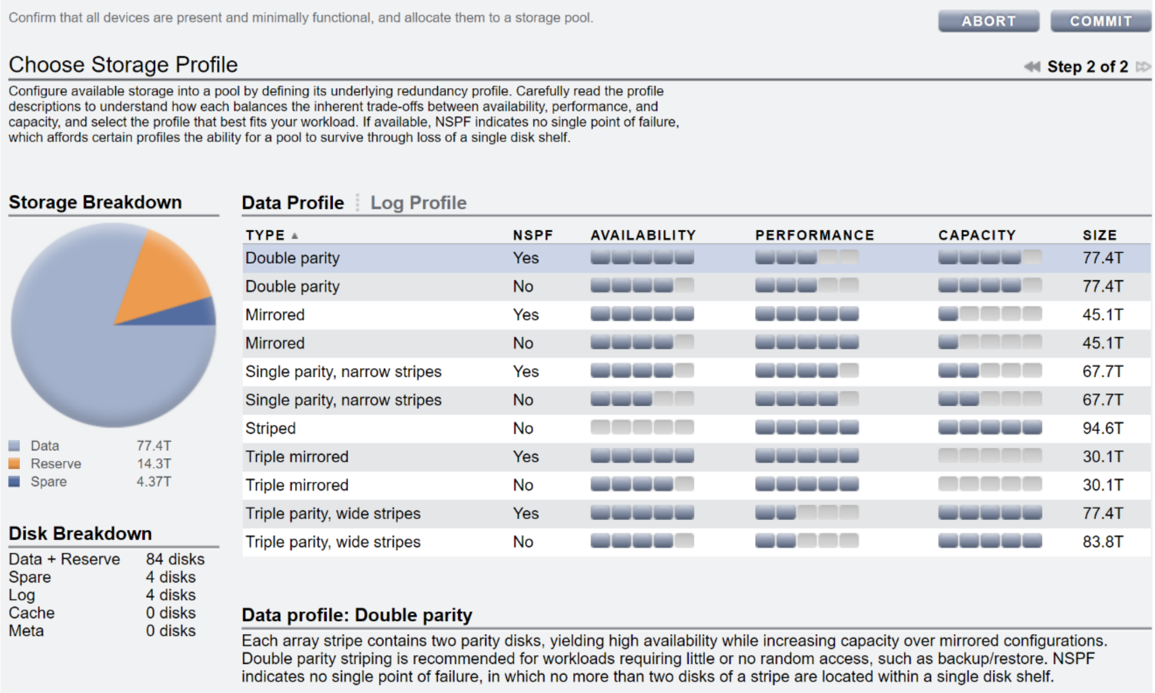
In an active/active backup environment each storage pool should be configured with half of the data disk drives in each Oracle Storage Drive Enclosure DE3-24C disk shelf. Each storage pool should also include half of the write-flash accelerators in each DE3-24C disk shelf. This allows for maximum performance and redundancy.

It is recommended to select the No Single Point of Failure (NSPF) option when configuring the storage pool. This ensures that the loss of an entire disk shelf does not compromise the availability of data. To enable NSPF a minimum of three disk shelves is needed for double-parity profiles.

Follow these steps to configure storage pools for an active/active standard backup deployment using the ZFS Storage Appliance's Browser User Interface (BUI).

Build a storage pool that will be primary on controller 1:

1. Access the BUI on **controller 1**, select **Configuration** > **Storage** and **configure a storage pool** by clicking the plus icon next to Available Pools.
2. **Provide a descriptive name** for the new storage pool. Controller 1 will have primary ownership for this storage pool. In this example the storage pool is named "BACKUP1". **Click apply** to move to the device allocation screen.
3. Select half of the data devices and half of the log devices **from each disk shelf** to be included in the storage pool. This method of device allocation will provide optimal performance and redundancy. **Select commit** to move to the storage profile configuration screen.
4. **Choose a data profile of double parity with NSPF**. For maximum redundancy it is recommended to select a log profile of mirrored. **Select commit** to complete the configuration and build the new storage pool.



Confirm that all devices are present and minimally functional, and allocate them to a storage pool.

Choose Storage Profile

Configure available storage into a pool by defining its underlying redundancy profile. Carefully read the profile descriptions to understand how each balances the inherent trade-offs between availability, performance, and capacity, and select the profile that best fits your workload. If available, NSPF indicates no single point of failure, which affords certain profiles the ability for a pool to survive through loss of a single disk shelf.

Storage Breakdown

▨	Data	77.4T
▨	Reserve	14.3T
▨	Spare	4.37T

Disk Breakdown

Data + Reserve	84 disks
Spare	4 disks
Log	4 disks
Cache	0 disks
Meta	0 disks

Data Profile | Log Profile

TYPE ▲	NSPF	AVAILABILITY	PERFORMANCE	CAPACITY	SIZE
Double parity	Yes	■■■■■	■■■□□	■■■■□	77.4T
Double parity	No	■■■■□	■■■□□	■■■■□	77.4T
Mirrored	Yes	■■■■■	■■■■■	■□□□□	45.1T
Mirrored	No	■■■■□	■■■■■	■□□□□	45.1T
Single parity, narrow stripes	Yes	■■■■□	■■■■□	■■□□□	67.7T
Single parity, narrow stripes	No	■■■□□	■■■■□	■■□□□	67.7T
Striped	No	□□□□□	■■■■■	■■■■■	94.6T
Triple mirrored	Yes	■■■■■	■■■■■	□□□□□	30.1T
Triple mirrored	No	■■■■□	■■■■■	□□□□□	30.1T
Triple parity, wide stripes	Yes	■■■■■	■■□□□	■■■■■	77.4T
Triple parity, wide stripes	No	■■■■□	■■□□□	■■■■■	83.8T

Data profile: Double parity

Each array stripe contains two parity disks, yielding high availability while increasing capacity over mirrored configurations. Double parity striping is recommended for workloads requiring little or no random access, such as backup/restore. NSPF indicates no single point of failure, in which no more than two disks of a stripe are located within a single disk shelf.

Figure 5. Choosing a storage profile

Build a storage pool that will be primary on controller 2:

1. Access the BUI on **controller 2**, select **Configuration** > **Storage** and **configure a storage pool** by clicking the plus icon next to Available Pools.
2. **Provide a descriptive name** for the new storage pool. Controller 2 will have primary ownership for this storage pool. In this example the storage pool is named "BACKUP2". **Click apply** to move to the device allocation screen.
3. Select the remaining data and log devices **from each disk shelf** to be included in the storage pool. **Select commit** to move to the storage profile configuration screen.
4. **Choose a data profile of double parity with NSPF**. For maximum redundancy it is recommended to select a log profile of mirrored. **Select commit** to complete the configuration and build the new storage pool.

Configuring the Projects and Shares

A project provides a single access and control point for managing filesystems (shares). Projects can be used for grouping logically related shares together. Shares within a project typically share common settings. Quotas can be enforced at the project level in addition to the share level.

It is recommended to use a project for managing the Oracle Exadata backup solution. Projects for different storage pools can share the same name.

Create a project for the BACKUP1 storage pool:

1. Access the BUI on **controller 1**, select **Shares > Projects** and **create a new project** by clicking the plus icon next to Projects.
2. **Provide a descriptive name** for the new project such as "bkup_x8m".
3. **Click apply** to create the new project.

Repeat this process to create a project on the BACKUP2 storage pool by accessing the BUI on **controller 2**.

Project settings can be configured so that any filesystem (share) created within the project with inherit settings from the project.

Optimize the new project settings for a standard RMAN backup use case:

1. Access the BUI on **controller 1**, select **Shares > Projects > "bkup_x8m" (project name) > General**.
2. **Configure the mountpoint.** A mountpoint of "/export/zs1" was used in this example.
3. **Select LZ4 compression**. LZ4 compression should be enabled on the storage. It provides additional benefit when combined with Oracle Database compression by reducing the bandwidth to back-end disk with only minor impact to Oracle ZFS Storage Appliance ZS7-2 CPU utilization.

   Physical network throughput is typically increased when using LZ4 since SAS bandwidth and disk utilization are often limiting factors.

   With Advanced Row Compression enabled for an OLTP Oracle Database, LZ4 typically provides additional space savings in the range of 1.8x to 2.4x.
4. **Set cache device usage to "do not use cache devices".** Read-optimized flash should not be used for caching standard Oracle RMAN workloads because there is little benefit from storing Oracle RMAN backup sets in cache. Moreover, the level 2 ARC is not intended for streaming workloads.
5. **Set synchronous write bias to throughput**. This is a share setting that controls behavior for servicing synchronous writes. It can be optimized for latency or throughput.

   All writes are initially written to the ZFS adaptive replacement cache (ARC), regardless of whether they are asynchronous, synchronous, latency-optimized, or throughput-optimized. Also, all writes are copied from the ARC to the storage pool.

   An asynchronous write returns an acknowledgement to the client after the write to ARC is complete. When synchronous writes are optimized for throughput, an acknowledgement is not returned until the write is copied to the storage pool.

   When synchronous writes are optimized for latency, an additional copy is written to persistent storage so that acknowledgements can be returned to the client faster. When write-optimized flash is configured in the storage pool, it is used as the persistent storage for latency-sensitive synchronous writes.

   Standard RMAN backup use cases generate bandwidth-sensitive workloads and writes are mostly asynchronous.
6. **Configure the record size to 1 MB**. The record size influences the size of back-end disk I/O.

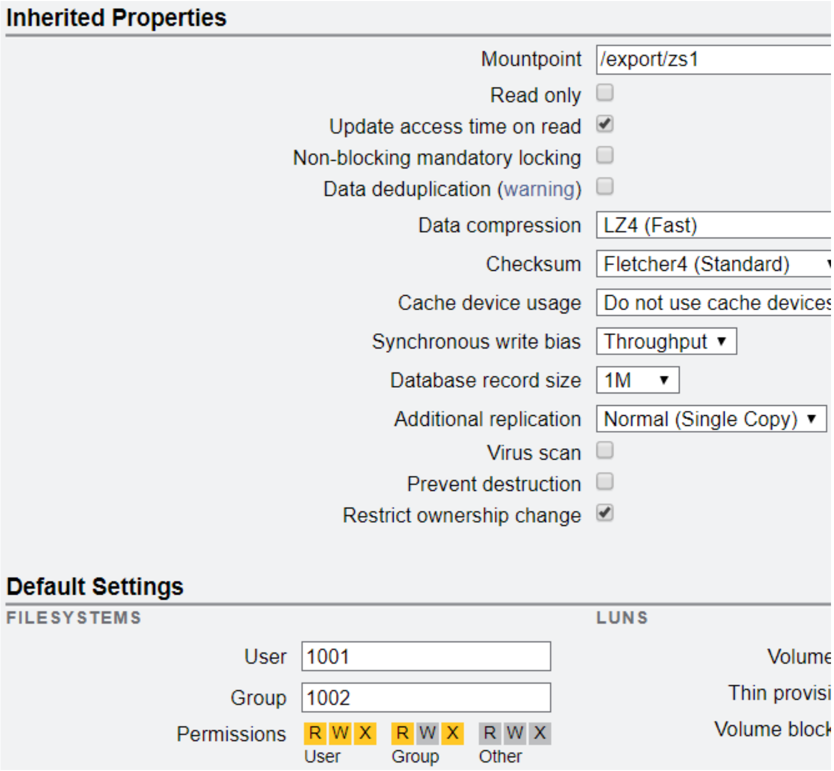
   Optimal settings depend on the network I/O sizes used by the application—in this case, Oracle RMAN. Standard Oracle RMAN workloads with Direct NFS Client generate large 1 MB writes and reads at the network layer. In this case, a 1 MB record-size setting should be used.

   The ability to use large record sizes has significant advantages, such as increased throughput performance, which is critical for bandwidth-intensive workloads. Other benefits include reduced utilization of controller CPU resources.

   In recent years, HDD capacities have grown as quickly as ever, yet the IOPS these disks can deliver has leveled off. Oracle RMAN workloads often generate datasets on the TB scale, with only a small frequency of read-backs. As such, caching is not an optimal solution for handling IOPS. Maximizing the throughput and limiting the IOPS to disk are important factors for achieving the best performance from the backup solution. Oracle RMAN standard backup strategies enable this by delivering large, multichannel network I/O that greatly benefits from large record sizes on the filesystem.

7. **Configure permissions for the oracle user (1001) and dba group (1002) with file access of 750**. Reference figure 6 for an example.
8. **Click apply** to configure the default settings for all shares in this project.

Repeat this process to optimize settings for the other storage pool's project by accessing the BUI on **controller 2**.



Inherited Properties

Mountpoint /export/zs1
Read only ☐
Update access time on read ☑
Non-blocking mandatory locking ☐
Data deduplication (warning) ☐
Data compression LZ4 (Fast)
Checksum Fletcher4 (Standard)
Cache device usage Do not use cache devices
Synchronous write bias Throughput
Database record size 1M
Additional replication Normal (Single Copy)
Virus scan ☐
Prevent destruction ☐
Restrict ownership change ☑

Default Settings

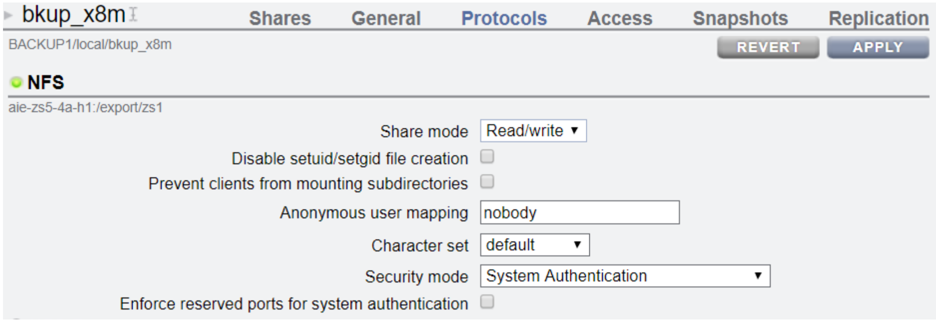
FILESYSTEMS
User 1001
Group 1002
Permissions R W X (User) R W X (Group) R W X (Other)

LUNS
Volume
Thin provisi
Volume block

Figure 6. Setting default share settings for each project

Configure the NFS share mode:

1. Navigate to **Shares** > **Projects** > **"bkup_x8m" (project name)** > **Protocols** and set the NFS share mode to **read/write**.
2. Ensure that the NFS protocols settings match figure 7 and then **click apply**.
3. **Repeat this step** for the other project.



BACKUP1/local/bkup_x8m

NFS
aie-zs5-4a-h1:/export/zs1

Share mode Read/write
Disable setuid/setgid file creation ☐
Prevent clients from mounting subdirectories ☐
Anonymous user mapping nobody
Character set default
Security mode System Authentication
Enforce reserved ports for system authentication ☐

Figure 7. NFS protocols settings for "bkup_x8m" project

The next step is to create the shares that will be mounted and accessed by the NFS clients.

Create a filesystem (share) for the BACKUP1 storage pool:

1. Access the BUI on **controller 1** and select **Shares** > **Projects** > **"bkup_x8m" (project name)** > **Shares**.
2. **Create a filesystem** by clicking on the plus icon next to Filesystems.
3. **Assign the filesystem a unique name**. This example creates a filesystem named "bkup_x8m_1". The filesystem will inherit the properties that were configured for the "bkup_x8m" project. No further configuration is required.
4. **Click apply** to create the filesystem.

Create a filesystem (share) for the BACKUP2 storage pool:

1. Access the BUI on **controller 2** and select **Shares** > **Projects** > **"bkup_x8m" (project name)** > **Shares**.
2. **Create a filesystem** by clicking on the plus icon next to Filesystems.
3. **Assign the filesystem a unique name**. This example creates a filesystem named "bkup_x8m_2".
4. **Click apply** to create the filesystem.

Two filesystems have been created, one on each storage pool.

Configuring the NFS Server

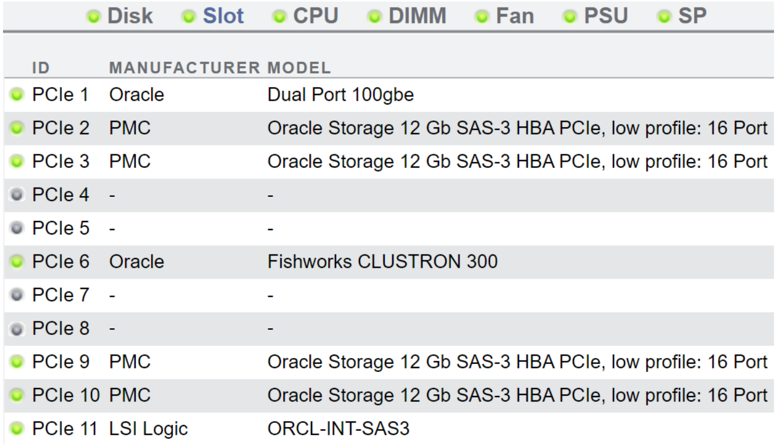
Start the NFS service and optimize settings:

1. Access the BUI and navigate to **Configuration** > **Services** and **select NFS**
2. **Ensure that the service is enabled and online**.
3. **Set the maximum supported version to NFSv4.1**.
4. **Configure the maximum # of server threads to 3000**.
5. **Click apply** to commit the changes.

It is only required to perform this step on one controller.

Configuring IO Cards

It is recommended that the Oracle ZFS Storage Appliance ZS7-2 high-end system be configured with four SAS-3 cards (slots 2, 3, 9 and 10) and one dual port 100Gb Ethernet card (slot 1) in each controller. Slot 1 is the only slot with a 16-lane configuration. Figure 8 shows the recommended PCIe configuration.



	ID	MANUFACTURER	MODEL
●	PCIe 1	Oracle	Dual Port 100gbe
●	PCIe 2	PMC	Oracle Storage 12 Gb SAS-3 HBA PCIe, low profile: 16 Port
●	PCIe 3	PMC	Oracle Storage 12 Gb SAS-3 HBA PCIe, low profile: 16 Port
○	PCIe 4	-	-
○	PCIe 5	-	-
●	PCIe 6	Oracle	Fishworks CLUSTRON 300
○	PCIe 7	-	-
○	PCIe 8	-	-
●	PCIe 9	PMC	Oracle Storage 12 Gb SAS-3 HBA PCIe, low profile: 16 Port
●	PCIe 10	PMC	Oracle Storage 12 Gb SAS-3 HBA PCIe, low profile: 16 Port
●	PCIe 11	LSI Logic	ORCL-INT-SAS3

Figure 8. Oracle ZFS Storage Appliance ZS7-2 high-end PCIe configuration

Configuring Data Path Network

The data path network is represented by the blue 100Gb QSFP28 ports in figure 9.

These interfaces are connected to the Cisco 9336C-FX2-OR 100Gb Ethernet switches that are configured as RoCE leaf switches in the Oracle Exadata X8M rack. Port 1 is connected to switch 1 and port 2 is connected to switch 2. Controller 1 connects to switch port 3 while controller 2 connects to port 35. Reference the network configuration chapter for detailed port mapping.

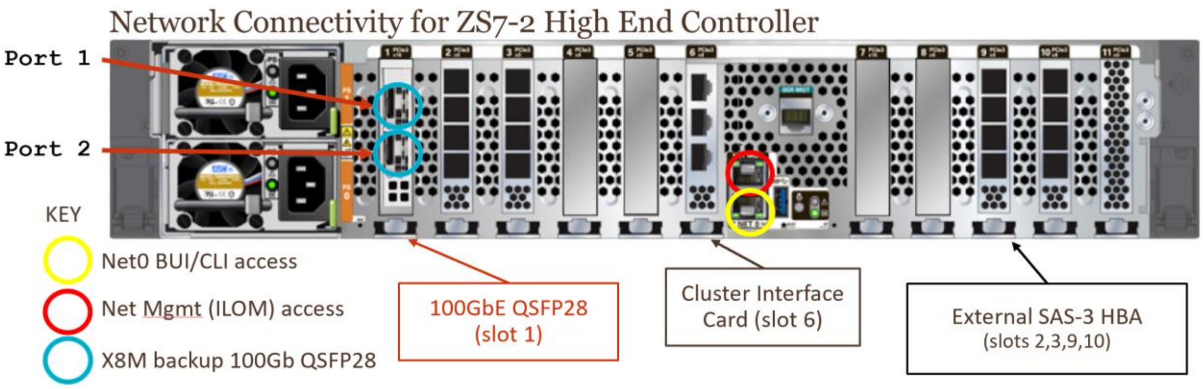

Network Connectivity for ZS7-2 High End Controller
Port 1
Port 2
KEY
Net0 BUI/CLI access
Net Mgmt (ILOM) access
X8M backup 100Gb QSFP28
100GbE QSFP28 (slot 1)
Cluster Interface Card (slot 6)
External SAS-3 HBA (slots 2,3,9,10)

Figure 9. 100Gb backup network connectivity for ZS7-2 high-end

An IPMP group is active on each controller to provide full HA redundancy. The Oracle Direct NFS Client can provide a level of HA, but currently relies on the kernel NFS mount for opening or creating files. IPMP is required to provide full HA in all situations.

A Virtual Network Interface Card (VNIC) is defined on the Oracle ZFS Storage Appliance to provide secondary access to the physical datalink. The physical datalink will provide data path services for the primary storage pool while the VNIC will provide data path services for the storage pool that is primary on the other controller.

Storage pools and the data path network are clustered resources and will transfer ownership during a controller failover.

Configuring Network Datalinks

Create a 100Gb physical datalink for mlxne0:

1. Access the BUI on **controller 1**, select **Configuration** > **Network** > **Configuration** and **build a new datalink** by clicking the plus icon next to the Datalinks column.

2. **Provide a descriptive name** for the new datalink. This datalink will provide primary data path for the BACKUP1 storage pool. Controller 1 has primary ownership for this storage pool. In this example the datalink's name is mlxne0-1.

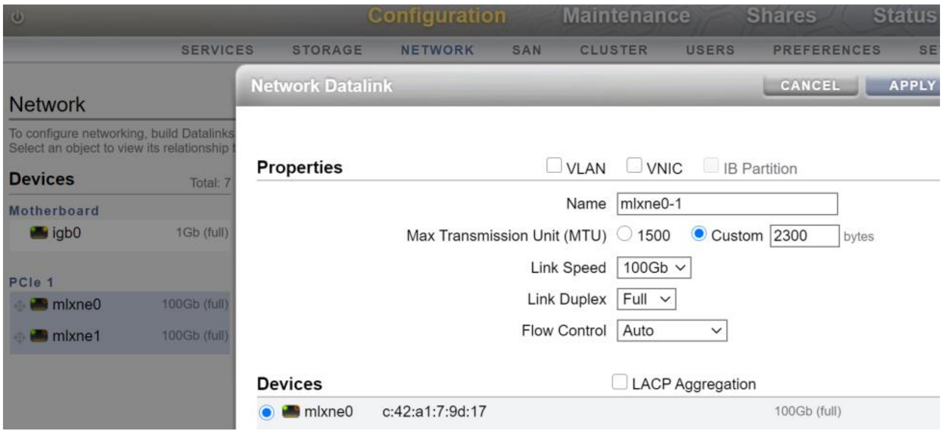
3. **Select the Maximum Transmission Unit** (MTU). The MTU setting helps determine the maximum packet size that can be communicated over the network.

   The default MTU is 1500 bytes. Larger MTUs improve performance for backup networks by allowing for more efficient processing of large streaming workloads with lower CPU overhead.

   The database server RoCE interfaces are optimized to use an MTU of 2300. **It is required to configure the 100Gb datalinks for an MTU of 2300 to match the clients.**

5. **Set the link speed to 100Gb and the duplex to full.** The Oracle Exadata X8M database server RoCE ports have auto negotiation disabled so the connecting 100Gb ZS7-2 ports must be configured to match.

6. **Click apply** to create the 100Gb physical datalink for mlxne0.



Network

To configure networking, build Datalinks
Select an object to view its relationship

Devices Total: 7

Motherboard

igb0 1Gb (full)

PCIe 1

mlxne0 100Gb (full)

mlxne1 100Gb (full)

Network Datalink

Properties □ VLAN □ VNIC □ IB Partition

Name: mlxne0-1

Max Transmission Unit (MTU): ○ 1500 ● Custom 2300 bytes

Link Speed: 100Gb

Link Duplex: Full

Flow Control: Auto

Devices □ LACP Aggregation

● mlxne0 c:42:a1:7:9d:17 100Gb (full)

Figure 10. Create 100Gb physical datalink

Create a 100Gb physical datalink for mlxne1:

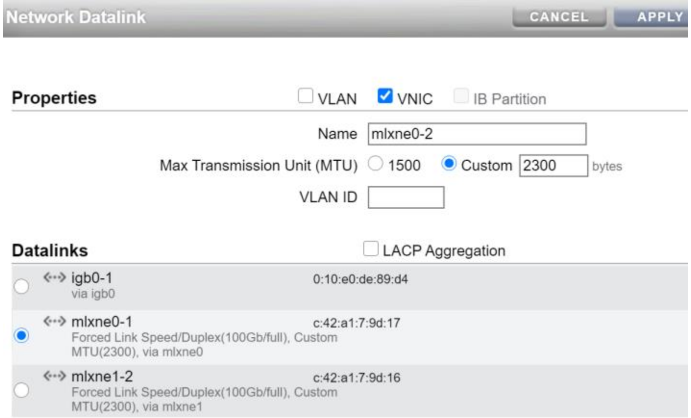
4. Access the BUI on **controller 2**, select **Configuration** > **Network** > **Configuration** and **build a new datalink** by clicking the plus icon next to the Datalinks column.
5. **Provide a descriptive name** for the new datalink. This datalink will provide primary data path for the BACKUP2 storage pool. Controller 2 has primary ownership for this storage pool. In this example the datalink's name is mlxne1-2.
6. **Select the Maximum Transmission Unit** (MTU). The database node RoCE interfaces are optimized to use an MTU of 2300. **It is required to configure the 100Gb datalinks for an MTU of 2300 to match the clients.**
7. **Set the link speed to 100Gb and the duplex to full.**
8. **Click apply** to create the 100Gb physical datalink for mlxne1.

Configuring VNIC Datalinks

VNICs datalinks are used in this solution to provide full network redundancy.

Create an VNIC of the physical datalink for mlxne0:

1. Access the BUI on **controller 2**, select **Configuration** > **Network** > **Configuration** and **build a new datalink** by clicking the plus icon next to the Datalinks column.
2. **Provide a descriptive name** for the new datalink. This datalink will provide standby data path for the BACKUP2 storage pool. Controller 2 has primary ownership for this storage pool. In this example the datalink's name is mlxne0-2.
3. **Configure the MTU.** Set the MTU to 2300 to match the previously created physical datalink.
4. **Select the VNIC checkbox** under properties and **add the previously created mlxne0 100Gb physical datalink**. Reference figure 11 for an example.
5. **Click apply** to create the VNIC datalink.



Properties ☐ VLAN ☑ VNIC ☐ IB Partition

Name: mlxne0-2

Max Transmission Unit (MTU): ○ 1500 ● Custom 2300 bytes

VLAN ID:

Datalinks ☐ LACP Aggregation

○ <··> igb0-1 0:10:e0:de:89:d4
via igb0

● <··> mlxne0-1 c:42:a1:7:9d:17
Forced Link Speed/Duplex(100Gb/full), Custom MTU(2300), via mlxne0

○ <··> mlxne1-2 c:42:a1:7:9d:16
Forced Link Speed/Duplex(100Gb/full), Custom MTU(2300), via mlxne1

Figure 11. Create a VNIC for 100Gb datalink

Create an VNIC of the physical datalink for mlxne1:

1. Access the BUI on **controller 1**, select **Configuration** > **Network** > **Configuration** and **build a new datalink** by clicking the plus icon next to the Datalinks column.
2. **Provide a descriptive name** for the new datalink. This datalink will provide standby data path for the BACKUP1 storage pool. Controller 1 has primary ownership for this storage pool. In this example the datalink's name is mlxne1-1.
3. **Configure the MTU.** Set the MTU to 2300 to match the previously created physical datalink.
4. **Select the VNIC checkbox** under properties and **add the previously created mlxne1 100Gb physical datalink**.
5. **Click apply** to create the VNIC datalink.

Confirm Switch Link Status

Login to switch1 as the admin user. Check status and confirm both ports have connected with the following settings before continuing.

```
switch1# show int Eth1/3,Eth1/35 status
--------------------------------------------------------------------------------
Port           Name                Status    Vlan      Duplex  Speed   Type
--------------------------------------------------------------------------------
Eth1/3         ZS72-1_100gb_p1     connected 3888      full    100G    QSFP-100G-CR4
Eth1/35        ZS72-2_100gb_p1     connected 3888      full    100G    QSFP-100G-CR4
```

Login to switch2 as the admin user. Check status and confirm both ports have connected with the following settings before continuing.

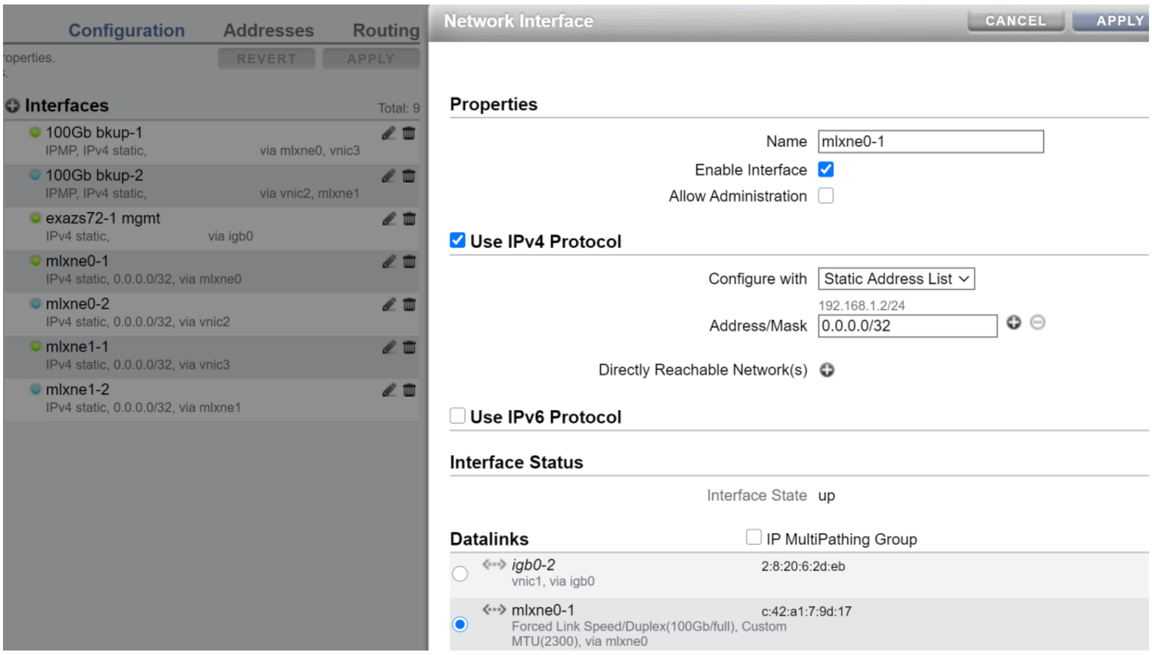
```
switch2# show int Eth1/3,Eth1/35 status
--------------------------------------------------------------------------------
Port           Name                Status    Vlan      Duplex  Speed   Type
--------------------------------------------------------------------------------
Eth1/3         ZS72-1_100gb_p2     connected 3888      full    100G    QSFP-100G-CR4
Eth1/35        ZS72-2_100gb_p2     connected 3888      full    100G    QSFP-100G-CR4
```

Configuring Network Interfaces

Interfaces are associated with datalinks and will function as members of IP multipathing groups.

Create an interface for mlxne0-1:

1. Access the BUI on **controller 1**, select **Configuration** > **Network** > **Configuration** and **build a new interface** by clicking the plus icon next to the Interfaces column.
2. **Provide a descriptive name** for the new interface. This interface will provide active data path for the BACKUP1 storage pool. Controller 1 has primary ownership for this storage pool. In this example the interface's name is mlxne0-1. Uncheck the allow administration box.
3. **Select the associated datalink** for this interface. Choose the mlxne0-1 datalink.
4. **Define an IP address** for this interface. This will be an underlying interface that is part of an IP multipathing group so set an IP address of 0.0.0.0/32. Reference figure 12 for an example.
5. **Click apply** to create the interface.



Interfaces Total: 9

100Gb bkup-1
IPMP, IPv4 static, via mlxne0, vnic3

100Gb bkup-2
IPMP, IPv4 static, via vnic2, mlxne1

exazs72-1 mgmt
IPv4 static, via igb0

mlxne0-1
IPv4 static, 0.0.0.0/32, via mlxne0

mlxne0-2
IPv4 static, 0.0.0.0/32, via vnic2

mlxne1-1
IPv4 static, 0.0.0.0/32, via vnic3

mlxne1-2
IPv4 static, 0.0.0.0/32, via mlxne1

Properties

Name: mlxne0-1
Enable Interface ☑
Allow Administration ☐

☑ Use IPv4 Protocol

Configure with: Static Address List
Address/Mask: 0.0.0.0/32 (192.168.1.2/24)
Directly Reachable Network(s)

☐ Use IPv6 Protocol

Interface Status

Interface State: up

Datalinks ☐ IP MultiPathing Group

○ igb0-2 — 2:8:20:6:2d:eb
vnic1, via igb0

● mlxne0-1 — c:42:a1:7:9d:17
Forced Link Speed/Duplex(100Gb/full), Custom MTU(2300), via mlxne0

Figure 12. Create a 100Gb underlying interface

Create an interface for mlxne1-1:

1. Access the BUI on **controller 1**, select **Configuration** > **Network** > **Configuration** and **build a new interface** by clicking the plus icon next to the Interfaces column.

2. **Provide a descriptive name** for the new interface. This interface will provide standby data path for the BACKUP1 storage pool. Controller 1 has primary ownership for this storage pool. In this example the interface's name is mlxne1-1. Uncheck the allow administration box.

3. **Select the associated datalink** for this interface. Choose the mlxne1-1 datalink.

4. **Define an IP address** for this interface. This will be an underlying interface that is part of an IP multipathing group so set an IP address of 0.0.0.0/32.

5. **Click apply** to create the interface.

Create an interface for mlxne0-2:

1. Access the BUI on **controller 2**, select **Configuration** > **Network** > **Configuration** and **build a new interface** by clicking the plus icon next to the Interfaces column.

2. **Provide a descriptive name** for the new interface. This interface will provide standby data path for the BACKUP2 storage pool. Controller 2 has primary ownership for this storage pool. In this example the interface's name is mlxne0-2. Uncheck the allow administration box.

3. **Select the associated datalink** for this interface. Choose the mlxne0-2 datalink.

4. **Define an IP address** for this interface. This will be an underlying interface that is part of an IP multipathing group so set an IP address of 0.0.0.0/32.

5. **Click apply** to create the interface.

Create an interface for mlxne1-2:

1. Access the BUI on **controller 2**, select **Configuration** > **Network** > **Configuration** and **build a new interface** by clicking the plus icon next to the Interfaces column.

2. **Provide a descriptive name** for the new interface. This interface will provide active data path for the BACKUP2 storage pool. Controller 2 has primary ownership for this storage pool. In this example the interface's name is mlxne1-2. Uncheck the allow administration box.

3. **Select the associated datalink** for this interface. Choose the mlxne1-2 datalink.

4. **Define an IP address** for this interface. This will be an underlying interface that is part of an IP multipathing group so set an IP address of 0.0.0.0/32.

5. **Click apply** to create the interface.

Creating IP multipathing groups

IPMP groups will be comprised of two interface members. They will provide full network redundancy.

Create an IP multipathing interface for the first storage pool:

1. Access the BUI on **controller 1**, select **Configuration** > **Network** > **Configuration** and **build a new interface** by clicking the plus icon next to the Interfaces column.

2. **Provide a descriptive name** for the new interface. This interface will provide data path for the BACKUP1 storage pool. Controller 1 has primary ownership for this storage pool. In this example the interface's name is 100Gb bkup-1.

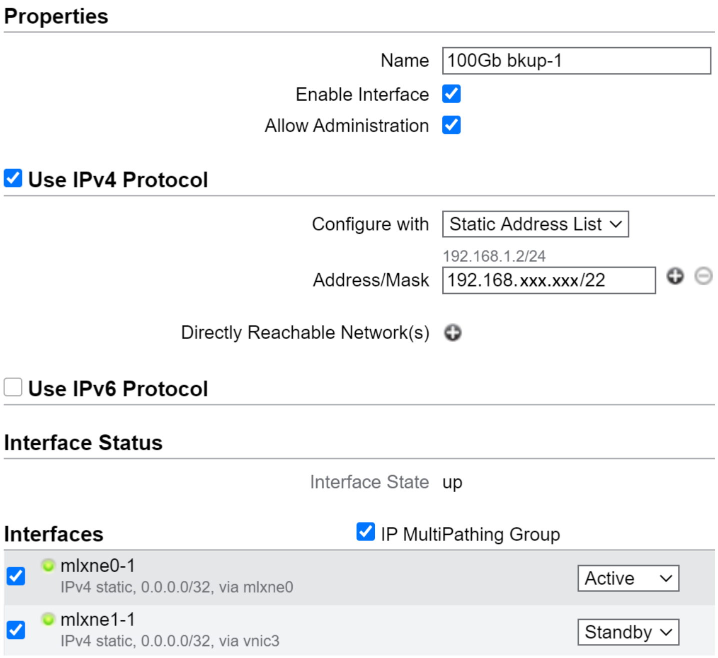
3. **Assign a unique IP address to this interface.** This will be the address used by the Oracle Exadata Database Servers to access the first storage pool. This example uses an address of 192.168.8.201/22. The default subnet for the RoCE network is 192.168.8.0/22 and database server RoCE interfaces typically start at 192.168.10.1. This interface must be configured with an available address on the RoCE network fabric.

4. **Configure the IP multipathing group.** Select the IP multipathing group checkbox. Add mlxne0-1 as an active interface to this group. Add mlxne1-1 as a standby interface to this group.

   In this configuration mlxne0-1 will serve as the primary data path interface for the BACKUP1 storage pool. The mlxne1-1 interface will serve as a standby and seamlessly take over if there is a fault or disruption in the network path to mlxne0-1. Because these are 100Gb interfaces, a single primary path can saturate the storage pool with no network bottlenecks.

An active-standby IPMP configuration consumes less CPU overhead than active-active. Reference figure 13 as an example.

5. **Click apply** to create the interface.



Properties

Name: 100Gb bkup-1

Enable Interface ☑

Allow Administration ☑

☑ **Use IPv4 Protocol**

Configure with: Static Address List

Address/Mask: 192.168.xxx.xxx/22 (192.168.1.2/24)

Directly Reachable Network(s)

☐ **Use IPv6 Protocol**

Interface Status

Interface State: up

Interfaces ☑ IP MultiPathing Group

☑	mlxne0-1 IPv4 static, 0.0.0.0/32, via mlxne0	Active
☑	mlxne1-1 IPv4 static, 0.0.0.0/32, via vnic3	Standby

Figure 13. Create an IP multipathing interface for data path

Create an IP multipathing interface for the second storage pool:

1. Access the BUI on **controller 2**, select **Configuration** > **Network** > **Configuration** and **build a new interface** by clicking the plus icon next to the Interfaces column.

2. **Provide a descriptive name** for the new interface. This interface will provide data path for the BACKUP2 storage pool. Controller 2 has primary ownership for this storage pool. In this example the interface's name is 100Gb bkup-2.

3. **Assign a unique IP address to this interface.** This will be the address used by the Oracle Exadata compute nodes to access the second storage pool. This example uses an address of 192.168.8.202/22. This interface must be configured with an available address on the RoCE network.

4. **Configure the IP multipathing group.** Select the IP multipathing group checkbox. Add mlxne1-2 as an active interface to this group. Add mlxne0-2 as a standby interface to this group.

5. **Click apply** to create the interface.

Enable adaptive routing for the multihoming policy to ensure that outbound traffic from an Oracle ZFS Storage Appliance system is spread over the network links and IP addresses. Access the BUI, select **Configuration** > **Network** > **Routing**, and then select option **multihoming=adaptive**.

Choosing Direct NFS Client

The Direct NFS Client feature of Oracle Database is highly recommended for all Oracle RMAN workloads between Oracle Exadata and Oracle ZFS Storage Appliance systems, and it is required to achieve optimal performance.

Direct NFS Client is a custom NFS client that resides within the Oracle Database kernel and provides several key advantages:

» Significantly reduces system CPU utilization by bypassing the OS and caching data just once in user space with no second copy in kernel space

» Boosts parallel I/O performance by opening an individual TCP connection for each Oracle Database process

» Distributes throughput across multiple network interfaces by alternating buffers to multiple IP addresses in a round-robin fashion

» Provides high availability (HA) by automatically redirecting failed I/O to an alternate address

These advantages enable increased bandwidth and reduced CPU overhead.

No additional steps are required on Oracle ZFS Storage Appliance systems to enable Direct NFS Client.

Oracle Intelligent Storage Protocol

Oracle Intelligent Storage Protocol, a feature of Oracle ZFS Storage Appliance systems, was introduced to interact with Direct NFS Client in Oracle Database 12*c*. It enables Oracle Database–aware storage by dynamically tuning record size and synchronous write bias on Oracle ZFS Storage Appliance systems. This simplifies the configuration process and reduces the performance impact of configuration errors. Hints are passed from the Oracle Database kernel to the Oracle ZFS Storage Appliance system. These hints are interpreted to construct a workload profile to dynamically optimize storage settings.

Oracle Intelligent Storage Protocol is an optional protocol that requires NFSv4 and SNMP. For instructions on how to enable Oracle Intelligent Storage Protocol, see My Oracle Support document 1943618.1 "Oracle ZFS Storage Appliance: How to Enable Oracle Intelligent Storage Protocol (OISP)."

Performance

An Oracle ZS7-2 high-end system in this solution is capable of sustaining single-database backup rates of **38.6TB/hr** and restore rates of **37.5TB/hr**. Achieving these rates is contingent on having an Oracle Exadata X8M configuration large enough and with enough available resources to support this performance. Small configurations and configurations with a heavy concurrent workload will have difficulty achieving maximum throughput rates that the storage can support. In our testing a quarter-rack X8M with Extreme Flash configuration recorded an average backup rate of 32.0TB/hr with a concurrent moderately-intense OLTP transaction workload running. All rates in this document were achieved using the recommended double parity storage profile with No Single Point of Failure (NSPF). NSPF provides redundancy even in extreme cases where an entire shelf of disks is taken offline.

In large configurations with plenty of available resources the smaller MTU size of 2300 is a limiting factor for backup and restore performance. In some cases, more RMAN channels may be necessary to saturate the hardware resources.

Storage Compression Benefit

The rates documented above were achieved while using storage LZ4 compression averaging 2.39x footprint reduction. This was in addition to Advanced Row Compression already in effect on the database. Total effective compression ratios during this testing were greater than 4x. LZ4 compression is compatible with both recommended types of database compression, Advanced Row Compression or Hybrid Columnar Compression (HCC). LZ4 compression increases the CPU load on the Oracle ZS7-2 controllers but is recommended due to the storage footprint reduction and increased performance that is often achieved due to reducing the load on backend disk.

Single Storage Pool

In scenarios with many databases on the Oracle Exadata X8M and where backups are typically run concurrently, better performance and simplicity can be achieved by backing up some of the databases to just one storage pool and some of the databases to just the other storage pool. An Oracle ZS7-2 high-end system in this solution is capable of sustaining single-pool backup rates of 20.5TB/hr and single-pool restore rates of 33.2TB/hr. Alternating between two NFS servers can negatively impact streaming efficiency. In scenarios with single large database or scenarios where backups are run serially, it is recommended to spread the backup across both storage pools.

Multi-section support to effectively utilize all available channels

Better performance is achieved when the RMAN work can be effectively run in parallel and all available channels are utilized. This occurs naturally when backing up or restoring a standard file tablespace. Since the underlying datafiles in a standard file tablespace are limited to 32GB there are typically many datafiles that can be processed independently by RMAN when backing up or restoring a database. Databases that use bigfile tablespaces can also achieve optimal performance, but more care should be taken to ensure that multi-section support is in place for both backup and restore. A backup configuration that exclusively processes one exceptionally large datafile with limited multi-section support will have difficulty achieving optimal performance from the storage hardware. Oracle recommends a 64GB section size. Additional details on RMAN configuration are provided in the next chapter.

CONFIGURING THE ORACLE EXADATA DATABASE MACHINE

This section provides best practices for configuring an Oracle Exadata X8M when using an Oracle ZFS Storage Appliance ZS7-2 to provide 100Gb Oracle Database protection with a standard RMAN backup strategy.

Backup Network

This architecture bypasses the backup network and leverages the RoCE interfaces (re0 and re1) on the database nodes to provide a 100Gb local backup solution. Other networking interfaces such as eth3, eth4, eth5 (optional) and eth6 (optional) are left available for client network, archive or disaster recovery (DR) functionality.

Oracle Exadata X8M database node network connectivity is represented in figure 14 and figure 15.

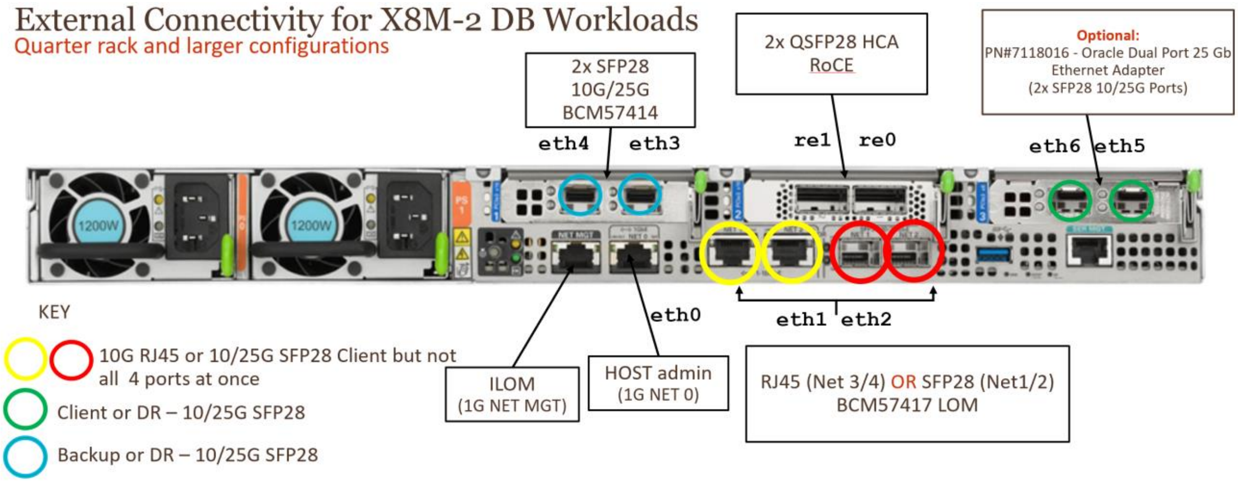

External Connectivity for X8M-2 DB Workloads
Quarter rack and larger configurations
2x SFP28 10G/25G BCM57414
2x QSFP28 HCA RoCE
Optional: PN#7118016 - Oracle Dual Port 25 Gb Ethernet Adapter (2x SFP28 10/25G Ports)
eth4
eth3
re1
re0
eth6
eth5
1200W
1200W
eth0
eth1
eth2
KEY
10G RJ45 or 10/25G SFP28 Client but not all 4 ports at once
Client or DR – 10/25G SFP28
Backup or DR – 10/25G SFP28
ILOM (1G NET MGT)
HOST admin (1G NET 0)
RJ45 (Net 3/4) OR SFP28 (Net1/2) BCM57417 LOM

Figure 14. Network connectivity for X8M-2 quarter rack or larger database nodes

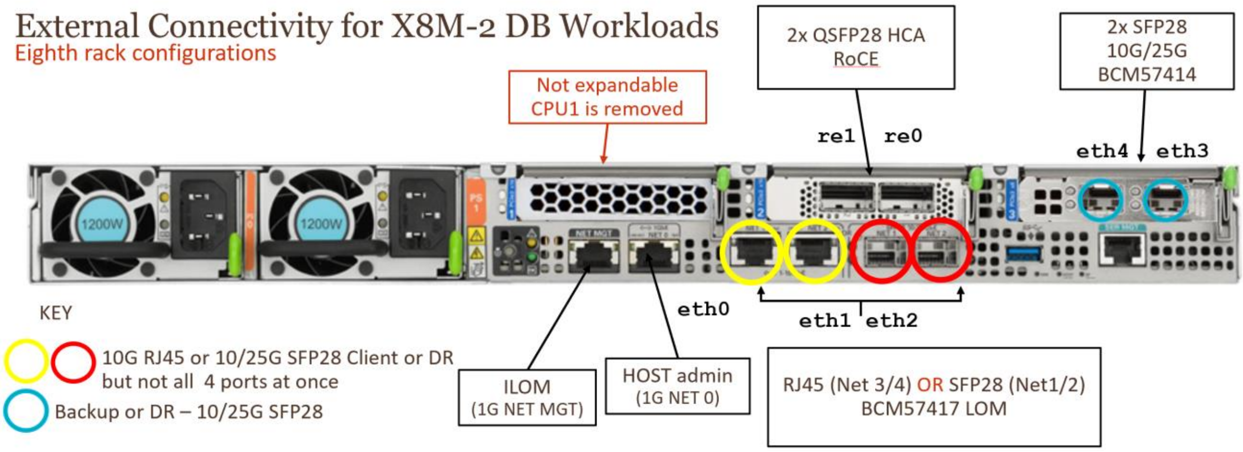

External Connectivity for X8M-2 DB Workloads
Eighth rack configurations
Not expandable CPU1 is removed
2x QSFP28 HCA RoCE
2x SFP28 10G/25G BCM57414
re1
re0
eth4
eth3
1200W
1200W
eth0
eth1
eth2
KEY
10G RJ45 or 10/25G SFP28 Client or DR but not all 4 ports at once
Backup or DR – 10/25G SFP28
ILOM (1G NET MGT)
HOST admin (1G NET 0)
RJ45 (Net 3/4) OR SFP28 (Net1/2) BCM57417 LOM

Figure 15. Network connectivity for X8M-2 eighth rack database nodes

The Oracle ZFS Storage Appliance uses 100Gb direct connections to the RoCE leaf switches. RMAN workloads leverage the database server re0 and re1 RoCE network fabric interfaces for high-speed local backup and restore operations to the ZS7-2.

The database server RoCE interfaces use active path management and do not require LACP or bonded configurations. These interfaces are configured during the Exadata deployment process and require no further modifications. Each database server is connected to the RoCE VLAN on both leaf switches in the rack. They use an MTU size of 2300.

Configure Backup Shares

The following mount options are recommended for shares dedicated to standard RMAN backup use cases:

```
rw,_netdev,hard,rsize=1048576,wsize=1048576,tcp,nfsvers=4,timeo=600 0 0
```

The Direct NFS Client does not utilize NFS mount options. However, setting the proper mount options is recommended to follow Oracle Database best practices and to improve performance and functionality if Direct NFS Client is not available and the system reverts to NFS.

Backup shares should be mounted on all Oracle Database nodes.

Mount the Oracle ZFS Storage Appliance backup shares:

1. **Edit the /etc/fstab** file to add entries like the following three-line example

   ```
   ######## lines added for zs7-2 with a 100Gb backup workload ########
   ```

   ```
   192.168.8.201:/export/zs1/bkup_x8m_1 /zfssa/zs1/bkup_x8m_1 nfs
   rw,_netdev,hard,rsize=1048576,wsize=1048576,tcp,nfsvers=4,timeo=600 0 0
   ```

   ```
   192.168.8.202:/export/zs1/bkup_x8m_2 /zfssa/zs1/bkup_x8m_2 nfs
   rw,_netdev,hard,rsize=1048576,wsize=1048576,tcp,nfsvers=4,timeo=600 0 0
   ```

   In this example, 192.168.8.201 is the data path IP address for the "BACKUP1" storage pool and 192.168.8.202 is the data path IP address for the "BACKUP2" storage pool. The export path of the filesystems are /export/zs1/bkup_x8m_1 and /export/zs1/bkup_x8m_2. The mount points on the compute nodes are /zfssa/zs1/bkup_x8m_1 and /zfssa/zs1/bkup_x8m_2.

2. **Copy these changes to the other compute nodes**.

3. **Create the /zfssa base directory** on all compute nodes (`mkdir /zfssa`) and change ownership to the oracle user and dba group (`chown oracle:dba /zfssa`).

4. As the oracle user, **create the mount points** used in the fstab on all compute nodes.

   ```
   ~]$ mkdir -p /zfssa/zs1/bkup_x8m_1
   ```

   ```
   ~]$ mkdir -p /zfssa/zs1/bkup_x8m_2
   ```

5. **Mount the backup shares** on all compute nodes.

   ```
   mount /zfssa/zs1/bkup_x8m_1; mount /zfssa/zs1/bkup_x8m_2
   ```

Configuring Direct NFS Client

In Oracle Database 12*c* and later, Direct NFS Client is enabled by default.

Confirm that Direct NFS Client is enabled by checking the Oracle Database alert log for an Oracle Disk Manager (ODM) message after Oracle Database startup:

```
Oracle instance running with ODM: Oracle Direct NFS ODM Library Version 6.0
```

Direct NFS Client activity can also be confirmed by SQL query:

```
SQL> select * from v$dnfs_servers;
```

Database v$ dnfs views will only be populated if Direct NFS Client IO has occurred since the last database start.

For a complete list of recommended patches for Direct NFS see My Oracle Support document 1495104.1 "Recommended Patches for Direct NFS Client."

Optional oranfstab

The oranfstab file is an optional configuration file that is required to use advanced features of Direct NFS. The Direct NFS client will still function without an oranfstab file and will use NFSv3 from a single source IP address to a single destination IP address. It is not required for this solution.

The oranfstab file configures load spreading of Direct NFS Client connections over multiple addresses on an Oracle ZFS Storage Appliance system (represented by "path") or multiple addresses on Oracle Exadata for Oracle Database (represented by "local"). Since the ZS7-2 data path network is using an active-standby IP multipathing configuration there will be just a single "path" IP address for each controller. The database server RoCE network uses active-active management with multiple IPs. X8M-2 configurations will have two "local" IP addresses.

The file is created in `$ORACLE_HOME/dbs/oranfstab` and applies to all Oracle Database instances that share `ORACLE_HOME`. When changes are made to the oranfstab file, the database should be bounced for the changes to take effect. NFSv4 is required to take advantage of Oracle Intelligent Storage Protocol (OISP). To enable NFSv4 for the Direct NFS, configure an oranfstab like the following example.

```
server: <STORAGE_NODE1>
local: 192.168.x.1 path: 192.168.x.201
local: 192.168.x.2 path: 192.168.x.201
nfs_version: nfsv4
export: /export/zs1/bkup_x8m_1 mount: /zfssa/zs1/bkup_x8m_1

server: <STORAGE_NODE2>
local: 192.168.x.3 path: 192.168.x.202
local: 192.168.x.4 path: 192.168.x.202
nfs_version: nfsv4
export: /export/bkup_x8m_2 mount: /zfssa/zs1/bkup_x8m_2
```

Configuring Oracle RMAN Backup Services

Oracle RMAN backup services should be created and used to balance Oracle RMAN workloads across all Oracle Exadata database servers. Spreading a backup across multiple Oracle Real Application Clusters (Oracle RAC) nodes improves performance, increases parallel tasks, and reduces utilization load on any single component. Oracle RMAN backup services are automatically migrated to other Oracle Exadata servers for Oracle Database in the Oracle RAC cluster when the preferred instance is unavailable.

The configuration steps below are an example of an admin-managed RAC database on an Exadata X8M-2 half rack with four Oracle RAC nodes. Hulk is the database name.

The syntax is: srvctl add service -d <db_name> -r <preferred instance> -a <alternate instance(s)> -s <name for newly created service>

```
[oracle@<HOSTNAME> ~]$ srvctl add service -d hulk -r hulk1 -a hulk2,hulk3,hulk4 -s hulk_bkup1
[oracle@<HOSTNAME> ~]$ srvctl add service -d hulk -r hulk2 -a hulk1,hulk3,hulk4 -s hulk_bkup2
[oracle@<HOSTNAME> ~]$ srvctl add service -d hulk -r hulk3 -a hulk1,hulk2,hulk4 -s hulk_bkup3
[oracle@<HOSTNAME> ~]$ srvctl add service -d hulk -r hulk4 -a hulk1,hulk2,hulk3 -s hulk_bkup4

[oracle@<HOSTNAME> ~]$ srvctl start service -d hulk -s hulk_bkup1
[oracle@<HOSTNAME> ~]$ srvctl start service -d hulk -s hulk_bkup2
[oracle@<HOSTNAME> ~]$ srvctl start service -d hulk -s hulk_bkup3
[oracle@<HOSTNAME> ~]$ srvctl start service -d hulk -s hulk_bkup4

[oracle@<HOSTNAME> ~]$ srvctl status service -d hulk
Service hulk_bkup1 is running on instance(s) hulk1
Service hulk_bkup2 is running on instance(s) hulk2
Service hulk_bkup3 is running on instance(s) hulk3
Service hulk_bkup4 is running on instance(s) hulk4
```

When the database is restarted the RMAN backup services should be rebalanced.

Preparing Oracle Database for Backup

Archivelog Mode

Archiving of the online redo logs is enabled when Oracle Database is configured to operate in “archivelog” mode. Benefits of using archivelog mode include

- Protection is provided in the event of media failure.
- Oracle Database transactions that occurred after the most recent backup can be recovered.
- Backups can be performed while Oracle Database is open and active.
- Inconsistent backups can be used to restore Oracle Database.

It is recommended that Oracle Database run in archivelog mode. It is also recommended that Data Guard is used to provide site recovery services. If Data Guard is not in use the archivelogs should be duplexed or multiplexed with the primary copy on Oracle Exadata storage and an optional copy on the Oracle ZFS Storage Appliance system.

Block-Change Tracking

Block-change tracking is an Oracle RMAN feature that records changed blocks within a datafile. The level 0 backup scans the entire datafile, but subsequent incremental backups rely on the block-change tracking file to scan just the blocks that have been marked as changed since the last backup.

It is recommended to enable block-change tracking to improve performance for incremental backups. If the chosen backup strategy includes only full or level 0 backups, block-change tracking should not be enabled.

Oracle RMAN Configuration

Compression

Oracle RMAN compression is suitable with Oracle ZFS Storage Appliance systems only when network bandwidth is limited. RMAN compression should not be used with local backups. It is far more efficient to rely on compression at the database level and at the storage level using LZ4 compression. RMAN compression is recommended for remote backups where network bandwidth is a limiting factor.

Oracle RMAN compression should not be used with Transparent Data Encryption (TDE) because it causes the data to be unencrypted, compressed, and re-encrypted during the backup session. This creates a major bottleneck for backup performance and places an enormous strain on Oracle Database CPU resources. Do not use RMAN encryption. TDE tablespace encryption is the recommended method.

Optimizing Channels

Determining the number of Oracle RMAN channels to use is an important aspect of tuning a backup solution. When Oracle RMAN opens a new channel, it allocates a new set of input and output buffers. Each channel can take a datafile or a section of a datafile and process the backup or restore job in parallel to work being done by other channels. Channels can be assigned to different nodes in the Oracle RAC cluster, and can have different backup destinations, with shares potentially owned by different Oracle ZFS Storage Appliance controllers.

Additional channels increase scalability and can provide significantly improved performance, more-efficient resource utilization, load balancing across Oracle Database nodes, a more robust HA architecture, and workload spreading between storage controllers.

As hardware limits are approached, allocating additional Oracle RMAN channels provides diminishing returns. It is not recommended to over-allocate channels because there is no performance gain, despite additional memory and CPU resources allocated for more Oracle RMAN buffers and added complexity in the form of more backup pieces being created.

Determining the recommended number of channels for a configuration depends on the hardware factor that will limit overall performance in an optimally configured solution. Performance limiting components could be many things, including Oracle Exadata or the network, HDD, CPU, or SAS resources. Thorough testing is always recommended when implementing major changes in a production environment. However, the following table provides guidance for how many Oracle RMAN channels to configure in a traditional Oracle RMAN backup strategy for each hardware configuration.

This table assumes an Oracle Exadata X8M-2 and an Oracle ZFS Storage ZS7-2 with storage balanced across both controllers. It assumes that network and SAS bandwidth are not limiting factors, that the best practices in this document are implemented, and that there are no other significant concurrent workloads during the backup window. When following these sizing guidelines, CPU resources consumed on the Exadata X8M database servers for RMAN workloads will always be less than 5%.

TABLE 5. SUGGESTED RMAN CHANNELS PER CONFIGURATION FOR A STANDARD BACKUP STRATEGY

	Channels per Oracle Exadata Eighth Rack	Channels per Oracle Exadata Quarter Rack	Channels per Oracle Exadata Half Rack	Channels per Oracle Exadata Full Rack
1 Disk Shelf	8	8	8	8
2 Disk Shelves	8	12	12	16
3–4 Disk Shelves	8	16	16	16

5–6 Disk Shelves	12	16	24	24
7–8 Disk Shelves	16	24	28	32
9+ Disk Shelves	16	24	32	40

When Oracle RMAN channels are configured or allocated, they should be alternated across the Oracle RAC nodes and storage shares.

Section Size

Enabling highly parallel Oracle RMAN workloads is critical for achieving optimal performance and resource utilization from the backup solution. One challenge is when an exceptionally large datafile is encountered. If it is processed by a single Oracle RMAN channel, throughput slows significantly, and other hardware resources in the environment sit idle while waiting for the outlier datafile processing to be completed.

Oracle RMAN's solution to this problem lies in its ability to break up large files into smaller pieces that can be processed in parallel by multiple channels. This is called multisection support and is determined by the section size parameter. It is recommended to set the section size to 64 gigabytes (`64G`).

Filesperset Parameter

The `filesperset` parameter determines how many datafiles or sections of datafiles are included in each backup set. When multiple input files are read to create a single backup set, it can improve performance, particularly when the read or copy phases are limiting factors. The default `filesperset` setting is 64; however, this is detrimental for single-file or partial Oracle Database restore operations because the entire backup set will be read back, even though only a small section is used. Also, an excessively large `filesperset` setting can impact the load balancing and performance scaling properties of Oracle RMAN. The objective is to have all Oracle RMAN channels effectively utilized throughout the backup. If there is a limited number of datafiles or data sections, it might not be possible to create full backup sets on every channel.

As a general practice, it is recommended to set the `filesperset` parameter to 1. Testing has shown that this provides excellent performance while load balancing across all channels. If deduplication is enabled, it is a requirement to set `filesperset` to 1. Including multiple files or sections in the same backup piece diminishes deduplication benefits.

Snapshot Control File

The snapshot control file is not part of the backup. It is a temporary file used by the Oracle RMAN process. It should be placed on local shared Exadata storage. Reference the sample run block for an example.

Sample Run Block

Here is a sample run block for a weekly level 0 backup that can be included as part of an incremental backup strategy. This example assumes an Oracle Exadata X8M-2 half rack backing up to both controllers (two storage pools) of an Oracle ZFS Storage Appliance configured with four disk shelves. Hulk is the name of the database used in this example. RMAN backup services are used to evenly spread channels across all four RAC nodes. Channels are alternated between the two storage shares with one owned by each controller. The first file handles persistent configurations and only needs to be run initially and again after any changes to RMAN settings. The second file would be run during every backup cycle.

```
RUN
{
CONFIGURE CHANNEL 1 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup1' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 2 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup2' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 3 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup3' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 4 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup4' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 5 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup1' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 6 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup2' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 7 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup3' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 8 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup4' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 9 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup1' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 10 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup2' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 11 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup3' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 12 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup4' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 13 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup1' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 14 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup2' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE CHANNEL 15 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup3' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
CONFIGURE CHANNEL 16 DEVICE TYPE DISK CONNECT 'sys/passwd@<SCAN_ADDRESS>/hulk_bkup4' FORMAT
'/zfssa/zs1/bkup_x8m_2/backup_%d_%U';
CONFIGURE DEVICE TYPE DISK PARALLELISM 16;
CONFIGURE CONTROLFILE AUTOBACKUP ON;
CONFIGURE CONTROLFILE AUTOBACKUP FORMAT FOR DEVICE TYPE DISK TO '/zfssa/zs1/bkup_x8m_1/ctrl_%F';
CONFIGURE SNAPSHOT CONTROLFILE NAME TO '+RECOC1/hulk/snapcf_hulk.f';
CONFIGURE ARCHIVELOG DELETION POLICY TO BACKED UP 1 TIMES TO DISK;
}
```

```
RUN
{
BACKUP AS BACKUPSET
  SECTION SIZE 64G
  INCREMENTAL LEVEL 0
  DATABASE
  FILESPERSET 1
  TAG 'bkup_weekly_L0';
}
```

Oracle Wallet Manager can be configured to avoid exposing passwords in RMAN run blocks. Instructions are available on how to configure and use Oracle Wallet Manager. When using RMAN backup with Oracle Wallet Manager, credential aliases using the <SCAN_ADDRESS>/<RMAN_SERVICE> should be defined in the wallet. The connect strings in the sample run block above are changed to hide the sys username and password as in the example below.

```
CONFIGURE CHANNEL 1 DEVICE TYPE DISK CONNECT '/@<SCAN_ADDRESS>/hulk_bkup1' FORMAT
'/zfssa/zs1/bkup_x8m_1/backup_%d_%U';
```

CONCLUSION

Oracle Exadata X8M leverages a new and improved networking infrastructure built on high-speed, low latency RDMA over Converged Ethernet fabric. The ZS7-2 is the first platform to offer a 100Gb backup solution by directly connecting to the internal Exadata 100Gb RoCE leaf switches. This bypasses the traditional backup network and provides a local backup option that is optimized for performance and simplicity. The architecture defined in this paper leverages the Oracle ZS7-2 and the local 100Gb network to provide a robust, fault-tolerant, and high-performance data protection solution.

Selecting the right backup solution for Oracle Exadata is an important decision. Costly third-party alternatives provide poor ROI and cannot support high-performance environments. Competitive offerings are inflexible and do not address all the customer's needs. Oracle ZFS Storage Appliance systems have proven to be an ideal solution for protecting the mission-critical data that resides on Oracle Exadata. Powerful features combined with custom Oracle-on-Oracle integrations enable a wide range of Oracle RMAN backup strategies. These provide outstanding performance and flexibility unmatched by third-party solutions.

Extreme restore throughput helps satisfy even the most stringent RTOs. Archive log multiplexing delivers recovery points of 20 minutes or less. Oracle Intelligent Storage Protocol, HCC, LZ4 storage compression, large 1 MB record sizes, data deduplication, and Direct NFS Client provide unique advantages when protecting Oracle Database.

In addition to data protection benefits, an Oracle Exadata backup solution using Oracle ZFS Storage Appliance systems provides many other advantages, such as low-cost, high-performance storage for unstructured data that resides outside of Oracle Database. It is easy to see why Oracle ZFS Storage Appliance systems offer an excellent solution for protecting Oracle Exadata.

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