Executive summary

Applications that are core to the success of your business are often classified as *mission critical* or business critical. Their tolerance for zero-downtime operations results in stringent service level agreements (SLAs) to achieve and maintain high levels of performance, availability, reliability and serviceability. Normally, addressing these requirements requires the application to be deployed upon bare metal operating environments, but advancements in hypervisor technologies now let you deploy these applications as virtualized workloads, for added scalability and rapid deployment.

Many organizations rely on virtualization to improve security and compliance requirements, increase datacenter flexibility, simplify deployment and management, improve operational efficiencies, and achieve lower total cost of ownership goals. To fully embrace and reap these benefits, adopting an integrated end-to-end solution can deliver the agility needed to accommodate the current needs and future growth requirements that mission-critical applications demand. Equally important, an integrated technology stack can enable you to expand, contract, scale up/down/out/in to address infrastructure allocation requirements as workloads change. To meet these needs, HP has created a converged infrastructure solution that combines HP networking, computing, and storage. The solution is proven, tested, and optimized to help you meet long-term datacenter needs for a variety of mixed application workloads—mission-critical or not.

HP ConvergedSystem 700x is a member of HP’s integrated datacenter rack configurations, which includes both hardware and software and provides:

- Integrated and validated technologies from an industry leader in computing, storage, networking and server virtualization
- A single converged platform capable of scaling to meeting datacenter requirements, based on a common architecture with shared technologies to non-disruptively address future demands
- Centralized management built on the integrated features of the physical components resulting in workload services based on a shared infrastructure pool
- Extensions that enable the seamless integration of additional HP hardware and software to extend the shared infrastructure into additional areas of IT—such as backup and recovery
- The capability to address workload demands of mission-critical, business-critical, and mixed-priority workloads

When it comes to mission-critical transactional and analytical workloads, Oracle databases are chief among the applications driving these workloads. More importantly, many major applications rely on Oracle database architectures within the application stack. Deploying a solid database architecture, virtually or physically, is a key success indicator that can mean the difference between leading and following your competition.

A solid database architecture can make the difference between competitive differentiation and simple comparative parity. Competitive organizations establish aggressive recovery point objectives (RPO) and recovery time objectives (RTO) to minimize data loss and ensure application recovery and restartability. They choose primary infrastructure and data protection strategies that must deliver application-consistent backups, application-restartable recoveries, user-defined service levels, single-points-of-failure eliminations, along with the ability to maximize resource utilization. Finding these requirements in a non-integrated solution is possible, but the longer-term application lifecycle costs are often much greater in the end.
Deployment procedures and best practices
This reference architecture identifies the deployment procedures and latest best practices to install, configure, protect and restore Oracle 12c with Oracle Automatic Storage Management (ASM) on Red Hat Enterprise Linux running in a VMware virtualized environment. The technology stack presented in this paper is a single HP solution based on HP hardware and software. The specific configuration and model identifiers are covered later in this document.

We will cover the following tasks:
• Design considerations concerning the ConvergedSystem 700x with HP Data Protector and HP StoreOnce
• Tuning and optimization considerations for backing up and restoring Oracle databases
• Tuning and optimization considerations for working with business critical applications in virtual environments
• Results and observations, based on workload testing efforts

All findings and performance-related information discovered during the design, qualification and testing of this architecture are covered.

Intended audience
This paper is suited for systems, storage and database administrators charged with deploying Oracle databases in a single-vendor converged technology stack (integrated computing, networking and storage) and integrated with a backup infrastructure to address the data protection strategies of the organization.

HP Data Protector and HP StoreOnce overview
For this reference architecture, the HP ConvergedSystem 700x is extended with HP Data Protector and HP StoreOnce to design a backup and recovery solution that addresses the needs of clustered Oracle databases that are virtualized on VMware’s hypervisor technology. This workload combination addresses both a common mission-critical and transactional workload running on a server virtualization technology. By basing the solution on the HP ConvergedSystem, customers benefit from a preloaded configured single HP software stack that includes servers, design, factory integrations, on-site installation, and proactive support with a single point of contact. The configuration is augmented to include HP Data Protector and HP StoreOnce.

The next section offers a baseline of the HP backup hardware and software used to create this reference architecture. The specific configuration of the reference architecture is covered in the section that follows.

HP Data Protector
HP Data Protector is a backup solution that provides reliable data protection and high availability for your fast-growing business data. Data Protector offers comprehensive backup and restore functionality specifically tailored for enterprise-wide and distributed environments. Following are major Data Protector features:

• Scalable and highly flexible architecture
  Data Protector can be used in environments ranging from a single system to thousands of systems on several sites. Due to the network component concept of Data Protector, elements of the backup infrastructure can be placed in the topology according to user requirements. The numerous backup options and alternatives to setting up a backup infrastructure allow the implementation of virtually any configuration. Data Protector also integrates seamlessly with HP StoreOnce and HP StoreEver backup appliances.

• Easy central administration
  Through its easy-to-use graphical user interface (GUI), Data Protector allows you to administer your complete backup environment from a single system. To ease operation, the GUI can be installed on several systems to allow multiple administrators to access Data Protector via their locally installed consoles. You can even manage multiple backup environments from a single system. The Data Protector command-line interface (CLI) allows you to manage Data Protector using scripts.
• **High-performance backup**
Data Protector enables you to perform backup to several hundred backup devices simultaneously, with support for high-end devices in very large libraries. Various backup possibilities, such as local backup, network backup, online backup, disk image backup, synthetic backup, backup with object mirroring, and built-in support for parallel data streams allow you to tune your backups to best fit your requirements.

**HP Data Protector Architecture**

• **Data Protector Cell Manager**
An HP Data Protector cell is a set of systems with a common backup policy existing on the same LAN/SAN. The Cell Manager is the main system that is the central point for managing this network environment. It contains the HP Data Protector internal database (IDB) and runs core HP Data Protector software and session managers. The Internal Database keeps track of backed up files and the cell configuration.

• **Data Protector Client**
A host system becomes a HP Data Protector client when one or more of the HP Data Protector software components are installed on the system. Client systems with disks that need to be backed up must have an appropriate Data Protector Disk Agent component installed. The Disk Agent enables you to back up data from the client disk or restore it. Client systems that are connected to a backup device must have a media agent component installed. This software manages backup devices and media.

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**Figure 1. HP Data Protector Architecture**

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**HP Data Protector Oracle Agent**

HP has developed a backup agent for Oracle databases. The integration links the Oracle management software with HP Data Protector, allowing Data Protector to manage all aspects of the backup, restore, and recovery operations for the Oracle database. With this integration Data Protector can start up and shut down the database, create/copy backups, restore/recover from backups, perform catalog maintenance/analysis, and perform stored script maintenance.

The integration agent for Oracle uses the RMAN functionality to direct Oracle server processes on the target database system to perform backup, restore, and recovery operations. Furthermore, the required information about the target database can be stored in the recovery catalog, the Oracle central repository of information, or in the catalog file of a particular database. The information in the recovery catalog enables Data Protector to make the determination regarding how to execute the request for backup and restore operations. With the Oracle Integration agent, Data Protector can backup and restore Oracle control files, data files, and archived and redo logs.
A backup that includes all data files and current control files that belong to an Oracle Server instance is known as a whole database backup. Data Protector Zero Downtime Backup (ZDB) can be used for online or offline backup of the Oracle target database. However, you must ensure that the backup objects (such as table spaces) are switched into the appropriate state before and after a backup session. For online backup, the database instance must operate in the ARCHIVELOG mode; whereas for offline backup, objects need to be prepared for backup using the Pre-exec and Post-exec options in the backup specification. The Data Protector backup specification contains information about backup options, commands for RMAN, Pre- and Post-exec commands, media, and devices.

Data Protector provides broad coverage for storage systems. In this reference architecture, Data Protector 8.11 is tested with HP 3PAR 7200 snapshot types:

- **Snapshot with pre-allocation of disk space** (standard snapshot).
- **Snapshot without pre-allocation of disk space** (virtually capacity-free snapshot or vsnap).
- **Complete copy of the source volume** (the virtual disk containing original data), which is independent of the source volume (snapclone) – using the 3PAR 7200 integration, the backup can be performed on disk, tape, and disk+tape media.

- **ZDB to disk**: The replica produced is kept on a disk array and presented to a Backup Host server. This replica becomes part of the replica set and can be used for instant recovery. ZDB to disk is performed if the option **Track the replica for instant recovery** is selected in a ZDB backup specification and **to disk** is selected when running/scheduling a backup.

- **ZDB to tape**: The replica produced presented to the Backup Host and streamed to backup media, typically tape, according to the tape backup type you have selected. This replica is deleted after backup if the option **Keep the replica after the backup is cleared** for the backup specification. If this option is selected, the replica remains on a disk array until it is reused and becomes part of the replica set. However, it cannot be used for recovery.

- **ZDB to disk+tape**: The replica produced is kept on a disk array and presented to the Backup Host to be streamed to backup media according to the tape backup type you select. This replica becomes part of the replica set and can be used for instant recovery. ZDB to **disk+tape** is performed if the option **Track the replica for recovery** is selected in a ZDB backup specification, and to **disk+tape** is selected when running/scheduling a backup.
**HP StoreOnce Backup**

The HP StoreOnce Backup System is a disk-based storage appliance for backing up multiple servers or PCs to target devices on the appliance. These devices are configured as Network-Attached Storage (NAS), StoreOnce Catalyst Stores or Virtual Tape Library (VTL) targets for backup applications. The total number of backup target devices provided by an HP StoreOnce Backup System varies according to model. These devices may be all StoreOnce Catalyst, all VTL, all NAS, or any combination of Catalyst, NAS, and VTL devices. All HP StoreOnce devices automatically make use of StoreOnce deduplication, ensuring efficient and cost-effective use of disk space. A further benefit of StoreOnce Catalyst devices is that deduplication may be configured to occur on the Media Server (low bandwidth) or on the StoreOnce Backup system (high bandwidth), allowing the user to decide what makes most efficient use of available bandwidth.

**HP StoreOnce and data deduplication**

HP StoreOnce Technology is a five-step “inline” data deduplication process (Chunk → Hash → Match → Compress → Store). It uses hash-based chunking technology, which analyzes incoming backup data in “chunks” that average 4K in size. The hashing algorithm generates a unique hash value that identifies each chunk and points to its location in the deduplication store.

Hash values are stored in an index that is referenced when subsequent backups are performed. When data generates a hash value that already exists in the index, the data is not stored a second time, but rather the count is increased showing how many times that hash code has been seen. Unique data generates a new hash code and that is stored on the appliance. Typically about 2% of every new backup is new data that generates new hash codes. With NAS shares, deduplication always occurs on the StoreOnce backup system. With Catalyst stores, deduplication may be configured to occur on the media server or on the StoreOnce backup system; these are also called low bandwidth mode or high bandwidth mode. See Figure 3 for a comparison of low and high bandwidth modes, where “Target side deduplication” corresponds to “High bandwidth mode” and “Source side deduplication” corresponds to “Low bandwidth mode.”

In low bandwidth mode the Catalyst integration allows for the processor-intensive deduplication tasks of chunking, hashing and compression to be “offloaded” onto the solution’s VMware Servers. Low bandwidth mode is also called source side deduplication and it has two main benefits, as follows:

1. It increases the overall throughput available on the HP StoreOnce appliance when receiving data streams that have already been chunked, hashed and compressed.
2. Low bandwidth backups make the process much more bandwidth efficient. If the backups are from remote sites they can be performed over a WAN or, if the media servers are in the data center, a much reduced network bandwidth from the media server to the HP StoreOnce appliance is required.

![Target Side Deduplication (High bandwidth)](image1)

![Source Side Deduplication (Low bandwidth)](image2)

**Figure 3.** Target side vs. source side StoreOnce deduplication
In high bandwidth mode, backup data is sent directly to the HP StoreOnce Backup System where it is deduplicated, which requires a high bandwidth network. This is also called target side deduplication. In this mode all deduplication steps like chunk, hash, match, compress and store are executed on the target StoreOnce Backup system.

A point worth noting here is that StoreOnce does not provide the option of setting low bandwidth or high bandwidth mode for a NAS share. For these two types of devices the deduplication always happens on the target device, such as StoreOnce Backup.

**HP StoreOnce for Oracle databases**

HP StoreOnce has been designed to cater to the needs of all types of customers from entry level to large scale enterprises. HP StoreOnce Backup systems deliver scale-out capacity and performance to keep pace with shrinking backup windows, reliable disaster recovery, simplified protection of remote offices and rapid file restore to meet today’s SLAs. The models vary by capacity and connectivity protocol and customers can start out by purchasing a single HP StoreOnce base unit/couplet, and then expand with additional couplets and expansion shelves. Table X lists the features of the HP StoreOnce model used in this reference architecture and recommendations for backing up Oracle databases.

<table>
<thead>
<tr>
<th>Table 1. HP StoreOnce for Oracle Databases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Description</strong></td>
</tr>
<tr>
<td><strong>Description and Use</strong></td>
</tr>
<tr>
<td><strong>Form Factor</strong></td>
</tr>
<tr>
<td><strong>Total Capacity</strong></td>
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<tr>
<td><strong>Device Interface</strong></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Transfer Rate</strong></td>
</tr>
</tbody>
</table>

HP StoreOnce is built using the HP Proliant server architecture, which means it shares common management tools with other HP Server products [e.g., HP Systems Insight Manager, HP Integrated Lights Out (iLO)]. This common architecture approach reduces the time and energy it takes to manage the IT infrastructure, and delivers these technologies on a standardized platform resulting in predictable and repeatable performance and interoperability characteristics.

**Reference Architecture environment**

This section focuses on the components used during the installation and deployment of two Oracle 12c RAC database clusters with Oracle ASM on Red Hat Enterprise Linux 6.5/6.3 x86_64. Both the application and operating system were run as virtual machines within a VMware virtual environment hosted on an HP ConvergedSystem 700x with HP Data Protector and HP StoreOnce to provide the advanced backup and recovery capabilities of the solution. Figure 1 provides a general systems overview of the solution supporting this effort.

**Hardware components and specifications**

The HP ConvergedSystem 700x is the hardware platform used for this reference architecture. It was augmented with additional HP hardware to complete the backup, recovery and archive infrastructure in accordance with the intent of this paper. The specific details concerning the configuration are described below:

- Hardware
  - HP Intelligent Infrastructure for Intelligent Rack and Power Infrastructure Management
  - HP BladeSystem c7000 Platinum enclosure(s)
  - HP VirtualConnect FlexFabric 10Gb/24-port Module
  - HP ProLiant BL460c Gen8 servers, with Intel Xeon processors E5-2600 v2 (workload)
– HP ProLiant DL360p Gen8 servers, with Intel Xeon processors E5-2600 v2 (management)
– HP 3PAR StoreServ 7200, 7400, 10400, or 10800 Storage
– HP 5120 EI Series and 5920 Series network switches
– HP StoreFabric SAN switches

• Management Software
  – HP Insight Control
  – HP Virtual Connect Enterprise Manager
  – VMware vCenter Server
  – HP Insight Control for VMware vCenter Server
  – HP Insight Control Storage Module for VMware vCenter Server
  – HP 3PAR StoreServe Operating Systems Software Suite and VMware extensions

Backup Hardware and Software
• HP StoreOnce Disk-to-Disk based backup solution
• (Optional) HP StoreEver MSL4048 for data archive
• HP Data Protector 8.11
  – Graphical User Interface installed on Microsoft Windows 2012 R2
  – Data Protector Cell installed on Red Hat Enterprise Linux 6.3
  – Licensed for Oracle Zero Downtime Backup, Instant Recovery, and Oracle Granular Recovery Extensions
  – Licensed for VMware Backups and Granular Recovery Extensions

**Hardware components and specifications**

The Oracle 12c RAC clusters were installed on VMware hosted virtual machines running Red Hat Enterprise Linux. A total of four virtual machines were grouped to form the Real Application Cluster with a total of two (2) clusters running on the HP ConvergedSystem 700x. Specific VMware components included:

• VMware vCenter Server v5.5
• VMware vSphere Server v5.5

**Operating System and Application specifications**

Additional applications running in the virtualized environment with direct and indirect relationships to this reference architecture include:

• Red Hat Enterprise Linux v6.3 & 6.4
• HammerDB v2.16
  – Installed on Microsoft Windows 2012 R2
• Oracle 12c Real Application Cluster (RAC)
  – Oracle Automated Storage Management (ASM)
  – Oracle Recovery Manager (RMAN)
• Microsoft Systems Center Operation Manager
**Infrastructure allocation**

*Figure 4*, below, demonstrates the logical layout of the hardware and software used in this document.

To accomplish this layout, the HP 3PAR StoreServ primary storage array, of the ConvergedSystem 700x, was used to allocate and present storage pools as described below for the workload purpose listed.

<table>
<thead>
<tr>
<th>Contents</th>
<th>RAID Type</th>
<th>Disk Type</th>
<th>Size</th>
<th>Provisioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oracle Data Files</td>
<td>Raid 5</td>
<td>15k SAS</td>
<td>20TB</td>
<td>Thin</td>
</tr>
<tr>
<td>Oracle Temp Files</td>
<td>Raid 6</td>
<td>NearLine</td>
<td>400GB</td>
<td>Thin</td>
</tr>
<tr>
<td>Oracle Redo Logs</td>
<td>Raid 1</td>
<td>SSD</td>
<td>400GB</td>
<td>Thick</td>
</tr>
<tr>
<td>Oracle Control Files</td>
<td>Raid 5</td>
<td>15k SAS</td>
<td>400GB</td>
<td>Thin</td>
</tr>
<tr>
<td>OS &amp; Binaries</td>
<td>Raid 5</td>
<td>15k SAS</td>
<td>400GB</td>
<td>Thin</td>
</tr>
<tr>
<td>HP Data Protector</td>
<td>Raid 5</td>
<td>15k SAS</td>
<td>300GB</td>
<td>Thin</td>
</tr>
<tr>
<td>VMware vCenter</td>
<td>Raid 5</td>
<td>15k SAS</td>
<td>200GB</td>
<td>Thin</td>
</tr>
</tbody>
</table>

Once allocated, the storage objects were presented to the VMware vSphere environment. The storage was allocated and provisioned using a thick format to optimize I/O performance during the workload testing phase of this solution.

<table>
<thead>
<tr>
<th>Contents</th>
<th>Size</th>
<th>Provisioning</th>
<th>VM Count</th>
<th>Operating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oracle Data Files</td>
<td>20TB</td>
<td>Thick</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oracle Temp Files</td>
<td>400GB</td>
<td>Thick</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oracle Redo Logs</td>
<td>400GB</td>
<td>Thick</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oracle Control Files</td>
<td>400GB</td>
<td>Thick</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OS &amp; Binaries</td>
<td>400GB</td>
<td>Thick</td>
<td>4</td>
<td>RHEL 6.3</td>
</tr>
<tr>
<td>HP Data Protector Cell Server</td>
<td>300GB</td>
<td>Thick</td>
<td>1</td>
<td>RHEL 6.3</td>
</tr>
<tr>
<td>VMware vCenter / Data Protector GUI</td>
<td>200GB</td>
<td>Thick</td>
<td>1</td>
<td>Windows Server 2012</td>
</tr>
</tbody>
</table>
In addition, two (2) virtual machine templates were defined to increase the speed of virtual machine deployments and remove the potential for inconsistencies in performance and virtual machine capabilities as part of this reference architecture. Table 3 presents the attributes for both templates, as the only difference is the operating system it is configured to use.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>14vCPUs</td>
</tr>
<tr>
<td>Memory</td>
<td>32GB</td>
</tr>
<tr>
<td>VM Settings</td>
<td>Latency Sensitivity = High</td>
</tr>
</tbody>
</table>

**Virtual Server configuration**

Based on the template details defined in Table 3 above, the following virtual machines were deployed with the specified workloads and, where appropriate, were bound to a cluster configuration to support the high availability needs of the Oracle database. The table below defines the virtual machines and their role in this reference architecture.

<table>
<thead>
<tr>
<th>Hostname</th>
<th>Description</th>
<th>Cluster Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>vmw38167.deu.hp.com</td>
<td>Windows 2012 with HP Data Protector 8.11 Cell Manager</td>
<td>NA</td>
</tr>
<tr>
<td>vmw35220.deu.hp.com</td>
<td>Backup Host for Zero Downtime Backup Service</td>
<td>NA</td>
</tr>
<tr>
<td>vmw38161.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
<tr>
<td>vmw38162.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
<tr>
<td>vmw38163.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
<tr>
<td>vmw38164.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
<tr>
<td>vmw38165.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
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<tr>
<td>vmw38166.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
<tr>
<td>vmw38168.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
<tr>
<td>vmw38169.deu.hp.com</td>
<td>ASM Cluster Node</td>
<td>cdbrac</td>
</tr>
</tbody>
</table>

**Network configuration**

Each layer in this reference architecture has redundant components to maximize availability. To remove single points of failure, the workload is deployed in a software-defined cluster, on top of a hypervisor configured for high availability, with redundancy built into the I/O pathways for infrastructure management, primary storage access, and the backup and recovery infrastructure. Figure 5 provides a graphical view of the networking interconnect.
SAN Fabric configuration

The HP ConvergedSystem 700x includes two fabric switches (as demonstrated in Figure X above) that is used to support the interconnect between the primary storage array and the compute nodes of the ConvergedSystem. To support virtualized environments, specific configuration settings must be set to gain optimum application performance in a virtualized deployment. Figure X graphically represents the SAN Fabric connectivity.

Figure 5. Network topology of the solution

Figure 6. SAN Fabric Configuration
Each node of the HP 3PAR StoreServe includes quad (4) port HBAs and the ports with the same node-pair/ID should be connected to the same fabric with odd ports connected to fabric 1 and even ports connected to fabric 2. Additionally, the HP 3PAR StoreServ must be configured specifically for the following SAN settings:

- Port Persistence with the following considerations:
  - The fabric must support NPIV and NPIV is enabled on all ports
  - Host facing ports configured for physical-to-physical ports
  - Host facing ports configured for target mode
  - The same host ports on the host-facing HBAs on each node of the pair are connected to the same fabric switch

- The StoreServ’s 8GB HBAs have a Queue Depth value set to 1092
- The StoreServ is configured for Single Initiator->Single Target zoning based on pWWN

**HP ConvergedSystem 700x Primary Storage Configuration**

The primary storage provided by the ConvergedSystem 700x is based on an HP 3PAR StoreServ storage array. To use HP Data Protector and HP StoreOnce with this array, the following integration steps are required:

- Export source volumes to the application server: Prior to performing this function, ensure all application and backup servers have been properly zoned with the HP ConvergedSystem 700x and that host objects for all application and backup systems have been created and configured.
- Install and configure Linux MPIO with the HP 3PAR StoreServ Component of the ConvergedSystem 700x:
  - Start the multipath daemon
  - Execute the command: `chkconfig multipathd on`
  - Navigate to `/etc/multipath.conf` file and add the following line to the defaults section of the file: `no_path_retry` fail to prevent the multipath device management software from queuing for unavailable disk volumes.

**Oracle 12c RAC setup considerations**

To take advantage of hardware-based snapshots, the core of Data Protector’s Zero Downtime Backup feature, the Oracle data files must be located on the primary storage volumes of the HP ConvergedSystem 700x and must be replicated using the disk array-based mirroring or snapshot features. The Oracle redo log files, archive log files and control files must be stored on a different physical volume/volume group from the database data files to prevent the recovery process from overwriting data and to support roll-forward recovery.

**Configuring Oracle Database Protection using HP Data Protector**

For this reference architecture, the HP Data Protector 8.1 integration with HP 3PAR Storage System Zero Downtime Backup solutions guide was used to configure the backup infrastructure with the primary storage of the HP ConvergedSystem 700x. Likewise, the Deploying Oracle 12c on RedHat Linux 6 Best Practice Guide was used as the source for the Oracle RAC deployment and setup. Both documents can be found here:

The results

Initial observations

In an effort to remain consistent in the backup infrastructure, the HP Data Protector Cell was deployed on the same operating system as the Oracle database cluster being protected. This isolated the management of VMware vCenter and the HP Data Protector graphical user interface to the single Microsoft Windows installation and removed potential performance implications between different operating systems within the backup infrastructure. This meant that both Oracle and the Data Protector Cell would run on RedHat Enterprise Linux version 6.5.

Once the clusters were created and the cell was deployed, it was discovered that Oracle removed the oracleasm tool (.../etc/init.d/oracleasm) from the RHEL 6.5 distribution. Regardless of Oracle’s business reason for removing this tool, the Zero Downtime Backup feature of Data Protector (the application-aware extension to perform application-consistent backups via snapshots on the primary storage array) relies on the oracleasm tool to complete the backup process. While a workaround was found on the Oracle website, efforts to install library packages and scripts to modify related files failed. More importantly, multiple online references recommended users to wait until RHEL version 6.6, which is the release that RedHat officially declared a re-insertion of the oracleasm tool.

To complete this reference architecture, the operating system was downgraded to RHEL version 6.3 to ensure access to the oracleasm tool and to complete the test conditions.

Capacity and sizing

Planning the capacity for backups is a complex process that is not just limited to the availability of physical storage for storing backups, the CPU/memory required on media servers, and even sizing the SAN and Ethernet links. For databases in general, and Oracle RAC in particular, backups are very critical for the uptime of a database. These backups are important not just for recovery in case of a failure, but if database logs are not backed up in a timely manner they could fill up the logs file system and potentially bring down the database. This scenario therefore merits proper capacity planning for database backups.

The considerations for arriving at the backup capacity required for an Oracle database are its size, the backup frequency, and the change (delta) that a database is witnessing. In traditional backup devices, the sizing would be a simple calculation of the space required for each backup and the number of backups to be retained. Today’s advanced backup technology is able to share, compress, encrypt, multiplex and deduplicate the data that is going to a backup media. Hence, sizing the capacity required for Oracle database backups is a complex process and there are several factors that play a role in it.

Presented below is a generic example; therefore, each customer’s actual storage requirements will differ accordingly from the example below.

Daily backup size (data) = 1TB (Per backup)
Daily backup size (logs) = 50 GB
(This assumes 100MB every five minutes for 24 hours. 288 log files will be generated, which adds up to 28,800MB or approximately 30GB. 50GB is used to be conservative.)

Maximum number of data backups on the StoreOnce device at any point in time.
= 7 daily, 5 weekly, 12 monthly, 7 yearly, 7 special
= 38 backups convert to 38TB

Maximum number of log backups on the StoreOnce device at any point in time.
= 50 GB * 14 (Assuming two weeks’ worth of logs on the disk)
= 700 GB

Total backup capacity required = 38.7TB or approximately 39TB

Deduplication ratio (data size on disk) = 2:1

( Assuming StoreOnce would deliver at least 2:1, although it is capable of delivering much more, and the actual Deduplication depends on the kind of data being written on the storage. Specific to this reference architecture testing demonstrated an average 13.5:1 deduplication ratio during test execution.)
Total backup capacity required on disk = 19TB
Available raw capacity on StoreOnce 4700 = 24 TB (2TB * 12 Disks)
Usable capacity with RAID6 protection = 19TB

Even for customers that have a higher backup frequency and need more backup space, the StoreOnce 4700 has ample scope for expansion and can be scaled up to 192TB (raw) and 160TB (usable). Moreover, a Backup Tape library is also proposed for vaulting/offsite purposes and this library can come in handy to ease any temporary space crunch.

**Workload description**

HP has done extensive testing to arrive at the achievable backup and restore performance of Data Protector for an Oracle database environment using HP StoreOnce. Figure X below shows the HP ConvergedSystem lab test setup.

![Figure 7. Logical view of the Oracle installation for this solution](image)

The testing was primarily aimed towards measuring the achievable throughput. Multiple tests were performed on each environment. The results could vary by 10% so the lower rate was chosen.

The Oracle database was deployed in a cluster configuration with two (2) clusters deployed in the virtual environment. The interoperability cluster, a minimal workload cluster with a database size no larger than 500GB, was used only as a baseline and kept as a pristine environment to validate settings and recommendations against. The results of the interoperability cluster are not reflected in the results below and were not discussed in any other detail in this document. The second Oracle cluster, the reference architecture cluster, was built to a size of 10TB. The file(s)/object(s) that were the source of these operations were timed and captured in the tables below.
Workload results: backup performance

The following backup tests were performed with varying LAN speeds and Data sizes. The average deduplication ratio of 14:1 was achieved with a daily data change rate of 1.00% using a 3.0:1 compression ratio with 50% of the total value being backed up. During the testing, 35 versions of the full backups were retained along with 48 versions of incremental backups. The total amount of backup data retained on disk was 4.8TB based on trending and analytics.

Table 6. CS 700x virtualized Oracle 12c RAC backup performance

<table>
<thead>
<tr>
<th>Server/Workload</th>
<th>Size</th>
<th>Time</th>
<th>Size</th>
<th>Time</th>
<th>Size</th>
<th>Time</th>
<th>Concurrent Backup Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full</td>
<td>Full</td>
<td>Diff</td>
<td>Diff</td>
<td>Incr</td>
<td>Incr</td>
<td>Streams</td>
</tr>
<tr>
<td>VMware vSphere</td>
<td>457GB</td>
<td>00:22</td>
<td>NA</td>
<td>NA</td>
<td>5GB</td>
<td>00:03</td>
<td>1</td>
</tr>
<tr>
<td>Oracle RMAN Extension</td>
<td>10TB</td>
<td>03:00</td>
<td>574GB</td>
<td>00:12</td>
<td>349MB</td>
<td>&gt;00:01</td>
<td>16</td>
</tr>
<tr>
<td>Oracle 12c RAC (1 node)</td>
<td>400GB</td>
<td>00:18</td>
<td>NA</td>
<td>NA</td>
<td>75MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
<tr>
<td>Oracle 12c RAC (2 nodes)</td>
<td>800GB</td>
<td>00:36</td>
<td>NA</td>
<td>NA</td>
<td>150MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
<tr>
<td>Oracle 12c RAC (3 nodes)</td>
<td>1.1TB</td>
<td>00:54</td>
<td>NA</td>
<td>NA</td>
<td>225MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
<tr>
<td>Oracle 12c RAC (4 nodes)</td>
<td>1.5TB</td>
<td>01:12</td>
<td>NA</td>
<td>NA</td>
<td>300MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
</tbody>
</table>

Observations/Notes

- The biggest impact on performance was the Network speed
- The size of the backup scaled linearly – e.g., if 1X (GB) took 30 min then 2X (GB) would take 1 hour to back up
- All calculations resulting in a decimal were rounded up to the next higher whole number for presentation and conservativeness
- HP Data Protector can achieve 50MB/s per backup/restore stream and multiple streams can be used simultaneously. With source-side deduplication (agent in the guest), up to 40 streams can be run, but for optimal performance, a total of 16 ensures a well-balanced transfer workload. Based on this, 16 streams * 50MB/s = 800MB/s, or 47GB/m, for the backup.
- HP Data Protector’s Virtual Environment Agent (for agentless backups of virtual machines) only uses a single backup/restore stream.
- The value maxopenfiles should be set to ’1’ which instructs Oracle to backup one file at a time per backup stream. This prevents Oracle from using multiplexing technologies to improve our deduplication ratios.
- Recommendations based on testing would be to create a backup configuration for Oracle 12c RAC that includes Incrementals (backing up archive logs) every 15 minutes, Differentials daily, and Fulls every 7 days.
- The virtual machines for the Oracle instance and the RedHat Linux OS install were allocated 400GB based on the defined template, but only consumed 76 – 78GB of disk space. The defined backup configuration for these included weekly full backups with daily incremental backups to ensure the least amount of data was transferred across the LAN to gain the best deduplication ratios possible.

Workload results: restore performance

While backups and backup speed is important and backups should be able to complete in a reasonable amount of time, it is also very important that the restore of the database is quick and smooth. HP tested the restoration of the Oracle database using both Oracle RMAN integrations and VMware host-level backups. The restore for an Oracle database instance can be initiated from the Oracle RMAN application. In addition, the virtual machine restore operations can be initiated from the HP Data Protector GRE for VMware. The Oracle recovery wizard guides a user through starting a restore with the integrations that HP Data Protector provides, performing the backend operations, and communications with the backup target devices.
### Table 7. CS 700x virtualized Oracle 12c RAC restore performance

<table>
<thead>
<tr>
<th>Server/Workload</th>
<th>Size Full</th>
<th>Time Full</th>
<th>Size Diff</th>
<th>Time Diff</th>
<th>Size Incr</th>
<th>Time Incr</th>
<th>Concurrent Backup Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMware vSphere</td>
<td>457GB</td>
<td>00:38</td>
<td>NA</td>
<td>NA</td>
<td>5GB</td>
<td>00:10</td>
<td>1</td>
</tr>
<tr>
<td>Oracle RMAN Extension</td>
<td>10TB</td>
<td>03:48</td>
<td>574GB</td>
<td>00:42</td>
<td>349MB</td>
<td>00:03</td>
<td>16</td>
</tr>
<tr>
<td>Oracle 12c RAC (1 node)</td>
<td>400GB</td>
<td>00:32</td>
<td>NA</td>
<td>NA</td>
<td>75MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
<tr>
<td>Oracle 12c RAC (2 nodes)</td>
<td>800GB</td>
<td>01:10</td>
<td>NA</td>
<td>NA</td>
<td>150MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
<tr>
<td>Oracle 12c RAC (3 nodes)</td>
<td>1.1TB</td>
<td>01:47</td>
<td>NA</td>
<td>NA</td>
<td>225MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
<tr>
<td>Oracle 12c RAC (4 nodes)</td>
<td>1.5TB</td>
<td>02:23</td>
<td>NA</td>
<td>NA</td>
<td>300MB</td>
<td>&gt;00:01</td>
<td>1</td>
</tr>
</tbody>
</table>

### General recommendations

• Oracle databases can only be recovered as a whole as well as tables and objects.

• Data Protector also supports point-in-time recovery operations, allowing the administrator to choose a specific snapshot to perform a recovery down to the second with the option to roll forward transaction logs as part of the process.

• In addition to the data and logs, there should also be a backup of the configuration files on the Oracle nodes. These files should be backed up before and after an upgrade of the Oracle database or any system changes are executed.

• Enable the log backups to initiate automatically rather than manually, this will ensure the logs space is always available and prevent the database from going down due to file system full condition.

• While successful backup is very important, it is also very important to ensure that the backup images are expiring in a timely manner. This indirectly ensures that there is sufficient capacity available on the backup device for routine future backups.

### Conclusion

Organizations invest in converged technology stacks to reap the benefits of a single pre-tested and validated solution platform that can help reduce risk, increase operational efficiencies, and deploy workloads upon a predictable infrastructure set. With a converged approach, you get a modular solution design that can scale with the demands and growth of your workloads. This provides you with a simplified and consistent approach to key processes for Oracle databases: data protection, recovery, disaster recovery, provisioning, cloning, replication, migration, etc. The One-HP solution built upon the ConvergedSystem 700x, with HP Data Protector and HP StoreOnce, supported, serviced and deployed by HP, removes the burdens of a build-it-yourself model and the long-term expense often tied to a multi-vendor strategy.

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