



The science behind the report:

A solution with Dell APEX Private Cloud and Dell APEX Data Storage Services Block delivered stronger Oracle Database performance at a lower cost than Amazon EBS io2 storage

This document describes what we tested, how we tested, and what we found. To learn how these facts translate into real-world benefits, read the report [A solution with Dell APEX Private Cloud and Dell APEX Data Storage Services Block delivered stronger Oracle Database performance at a lower cost than Amazon EBS io2 storage](#).

We concluded our hands-on testing on September 1, 2023. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on August 29, 2023 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

Our results

To learn more about how we have calculated the wins in this report, go to <http://facts.pt/calculating-and-highlighting-wins>. Unless we state otherwise, we have followed the rules and principles we outline in that document.

Performance

Table 1: Results of our performance testing.

Silly Little Oracle® Database results	Dell Technologies APEX solution	Amazon EBS io2
IOPS	348.941	317.566
Average database throughput	2.754	2,506

Cost

Table 2: Breakdown of total monthly cost in US dollars to run 16 x 1TB Amazon EBS io2 volumes, each with an average performance rate of 22,000 provisioned IOPS assuming a 730-hour month. Cost info current as of September 5, 2023. Source: Principled Technologies.

Amazon EBS io2 Storage cost analysis			
Monthly rate	Per volume	Total usage (16 volumes)	Monthly cost
Storage			
\$0.125/GB	1 TB	16 TB	\$2,000.00
Provisioned IOPS			
\$0.065/IOPS	22,000 IOPS	352,000 IOPS	\$22,880.00
Total monthly cost			\$24,880.00

Table 3: Breakdown of total monthly cost in US dollars for 1- and 3-year subscriptions to a Dell Technologies APEX solution with 50TB of Balanced-tier block storage assuming a 730-hour month. Cost info current as of September 5, 2023. Source: Principled Technologies.

Dell Technologies Dell APEX Private Cloud and Dell APEX Data Storage Services Block solution cost analysis	
APEX Private Cloud and APEX Data Storage Services Block monthly cost (50TB)	
1-year subscription (total monthly rate)	\$19,348.85
3-year subscription (total monthly rate)	\$13,439.43

System configuration information

Table 4: Detailed information on the systems we tested.

System configuration information	4 x APEX Private Cloud server
BIOS name and version	Dell 1.8.2
Non-default BIOS settings	None
Operating system name and version/build number	VMware ESXi 8.0.0 build-20513097
Date of last OS updates/patches applied	03/09/2023
Power management policy	Performance
Processor	
Number of processors	2
Vendor and model	Intel Xeon Platinum 8358
Core count (per processor)	32
Core frequency (GHz)	2.60
Stepping	6
Memory	
Total memory in system (GB)	512
Memory module(s) A	
Number of memory modules	16
Vendor and model	Hynix HMAA4GR7CJR8N-XN
Size (GB)	32
Type	DDR-4
Speed (MHz)	3,200
Speed running in the server (MHz)	3,200
Storage controller	
Vendor and model	Dell Boss-S2
Cache size	None
Firmware version	2.5.13.4008
Local storage	
Number of drives	2
Drive vendor and model	Micron MTFDDAV480TDS
Drive size (GB)	480
Drive information (speed, interface, type)	SSD, 6Gb SATA, HDD
Network adapter	
Vendor and model	Broadcom Adv Dual 25Gb
Number and type of ports	2 x 25GbE

System configuration information		4 x APEX Private Cloud server
Fibre Channel adapter		
Vendor and model	Emulex LPe35002-M2-D	
Number and type of ports	2 x 32Gb SFP	
Cooling fans		
Vendor and model	Dell	
Number of cooling fans	6	
Power supplies		
Vendor and model	Dell OM63JNA01	
Number of power supplies	2	
Wattage of each (W)	2,400	

Table 5: Detailed configuration information for the storage solution.

Storage configuration information		APEX Data Storage Services
Controller firmware revision	3.2.1.0	
Number of storage controllers	2	
Number of storage shelves	1	
Number of drives per shelf	12	
Drive vendor and model number	Dell 005053081	
Drive size (GB)	7,000	
Drive information (speed, interface, type)	NVMe SSD	

Table 6: Detailed configuration information for the AWS instance we tested.

AWS instance configuration information	
Tested by	Principled Technologies
Test date	9/1/2023
CSP / Region	East US 1
Workload & version	Oracle SLOB 2.5.4.0
WL specific parameters	24 Users
Iterations and result choice	3 runs, median
Server platform	m6i.16xlarge
Operating system name and version/build number	Oracle Linux 8.8
Date of last OS updates/patches applied	8/29/2023

AWS instance configuration information	
Local storage	
OS	
Number of drives	1
Drive size (GB)	100
Drive information (speed, interface, type)	gp3 Standard SSD
Oracle	
Number of drives	4
Drive size (GB)	1000
Drive information (speed, interface, type)	io2 (22000 IOPS)

How we tested

For this project, we used Oracle Database 21c and the SLOB toolkit to test the storage performance of two solutions; a Dell APEX balanced hybrid-cloud solution with four Dell APEX Private Cloud servers for the compute nodes and APEX Data Storage Services for the backend storage, and an AWS EC2 solution with io2 volumes. We created four VMs, or instances, on each solution with 64 vCPUs and 256 GB of RAM. For the APEX environment, we created four VMs (one per node) and sixteen 1TB RDM volumes and mapped four volumes to each VM. On AWS we created four m6i.16xlarge instances with sixteen 1TB io2 volumes and mapped four volumes to each instance. We then used SLOB to generate a roughly 1TB dataset and run the tests.

Creating the VM on AWS

1. Log into AWS and navigate to the AWS Management Console.
2. Click EC2.
3. Click Launch instance, and, from the drop-down menu, select Launch instance to open the Launch Instance wizard.
4. In the search window, type Oracle Linux 8 update 8 for x86_64 HVM and press enter.
5. On the Choose AMI tab, click the Select button next to Oracle Linux 8 update 8 for x86_64 HVM.
6. On the Choose Instance Type tab, select m6i.16xlarge, and click Next: Configure Instance Details.
7. On the Configure Instance tab, set the following:
 - Number of instances: 4
 - Purchasing option: Leave unchecked
 - Network: Default VPC
 - Subnet: Choose the region you're working in
 - Auto-assign Public IP: Enable
 - Placement Group: Leave unchecked
 - Capacity Reservation: Open
 - Domain join directory: No Directory
 - IAM role: None
 - Shutdown behavior: Stop
 - Click Next: Add Storage
8. On the Add Storage tab, set the following:
 - Size: 1,000
 - Volume Type: io2
 - IOPs limit: 22,000
 - Delete on Termination: Checked
 - Encryption: Not Encrypted
 - Click Next: Add Tags
9. On the Add Tags tab, set any tags, and click Next: Configure Security Group
10. On the Configure Security Group tab, keep defaults, and click Review and Launch.
11. On the Review Tab, click Launch.
12. Choose the appropriate option for the key pair, and click Launch Instances.

Creating the RDM LUNs on APEX

1. Log into the APEX Data Storage Services management console.
2. From the APEX Data Storage Services management interface, select the Storage drop-down menu, and click Volumes.
3. Under Volumes, click Create.
4. For Properties, provide a name for the volume, set the Quantity to 16, set the size (1TB), and click Next.
5. For Host Mappings, select all four hosts, and click Next.
6. Review the Summary, and click Create.

Creating the VM on APEX

1. In VMware vCenter, navigate to Virtual Machines.
2. To create a new VM, click the icon.
3. Leave Create a new virtual machine selected, and click Next.
4. Enter a name for the virtual machine, and click Next.
5. Place the VM on the desired host with available CPUs, and click Next.
6. Select the datastore to host the VM, and click Next.
7. Select the appropriate guest OS, and click Next.
8. In the Customize Hardware section, use the following settings:
 - Set the vCPU count to 64.
 - Set the Memory to 256GB.
 - Add 1x 100GB VMDK for OS.
 - Add 4x 1TB RDM LUN.
 - Create three additional VMware Paravirtual SCSI controllers, and assign each RDM to a different controller.
 - Attach the installation ISO to the CD/DVD drive.
9. Click Next.
10. Click Finish.

Installing Oracle Linux 8.8

1. Boot to the Oracle Linux 8.8 installation media.
2. Select Install or upgrade an existing system.
3. Choose English, and click Continue.
4. Under Installation Destination, select the desired disk to install the OS.
5. Under Other Storage Options, select I will configure partitioning, and click Done.
6. Select Click here to create them automatically.
7. Expand the swap partition to 32GB.
8. Assign all remaining free space to the / partition.
9. Click Done.
10. Click Accept Changes.
11. Select kdump.
12. Uncheck Enable kdump, and click Done.
13. Select Network & Hostname.
14. Enter the desired hostname for the system.
15. Turn on the desired network ports, and click Configure.
16. On the General tab, select Automatically connect to this network when it is available.
17. On the IPv4 Settings tab, choose the drop-down named Method, and select Manual.
18. Under Addresses, click Add, and enter the desired static IP information for the server.
19. Enter the desired DNS information.
20. Click Save, and click Done.
21. Click Software Selection.
22. Choose the Base Environment of Server with a GUI.
23. Click Done.
24. Click Begin Installation.
25. Select Root Password.
26. Enter the desired root password, and click Done.
27. When the installation completes, select Reboot to restart the server.

Configuring Oracle Linux 8.8

1. Log onto the server as root.
2. Change default kernel:

```
yum -y install kernel-4.18.0-477.13.1.el8_8.x86_64  
grubby --set-default /boot/vmlinuz-4.18.0-477.13.1.el8_8.x86_64
```

3. Use visudo to add the following to the end of /etc/sudoers:

```
username ALL=(ALL) NOPASSWD:ALL
```

4. Download and install OracleASM support and lib packages:

```
yum -y install wget  
wget https://public-yum.oracle.com/repo/OracleLinux/OL8/addons/x86_64/getPackage/oracleasm-  
support-2.1.12-1.el8.x86_64.rpm  
wget https://download.oracle.com/otn_software/asmlib/oracleasmlib-2.0.17-1.el8.x86_64.rpm  
yum -y localinstall oracleasm*
```

5. Install the Oracle Database 21c pre-install:

```
yum -y install oracle-database-preinstall-21c xhost kmod-oracleasm
```

6. Update the host:

```
yum -y update
```

7. Create passwords for the oracle account with passwd.
8. Create a partition on all disks using gdisk.
9. Edit /etc/sysconfig/oracleasm and change the following:

```
ORACLEASM_ENABLED=true  
ORACLEASM_UID=oracle  
ORACLEASM_GID=oinstall
```

10. Run the following command to initialize oracleasm:

```
oracleasm init  
oracleasm createdisk DATA1 /dev/sdb1  
oracleasm createdisk DATA2 /dev/sdc1  
oracleasm createdisk DATA3 /dev/sdd1  
oracleasm createdisk DATA4 /dev/sde1
```

11. Reboot the host.
12. Log onto the server as root.
13. Disable the firewall:

```
systemctl stop firewalld  
systemctl disable firewalld
```

14. Disable auditd:

```
systemctl disable auditd
```


15. Disable SELinux:

```
vi /etc/selinux/config
SELINUX=disabled
```

16. Reboot the host.

Preparing Linux for Oracle Database 21c Installation

1. Log onto the server as root.
2. Create the following directories and assign the following permissions:

```
mkdir -p /u01/app/oracle/product/21.0.0/dbhome_1
mkdir -p /u01/app/21.0.0/grid
mkdir -p /u02/oradata
chown -R oracle:oinstall /u01 /u02
chmod -R 775 /u01 /u02
mkdir /home/oracle/scripts
```

3. Create the environment variable script setEnv.sh:

```
# Oracle Settings
export TMP=/tmp
export TMPDIR=$TMP

export ORACLE_HOSTNAME=[Hostname]
export ORACLE_UNQNAME=orcl
export ORACLE_BASE=/u01/app/oracle
export GRID_HOME=/u01/app/21.0.0/grid
export ORACLE_HOME=$ORACLE_BASE/product/21.0.0/dbhome_1
export ORA_INVENTORY=/u01/app/oraInventory
export ORACLE_SID=orcl
export PDB_NAME=orclpdb1
export DATA_DIR=/u02/oradata
export BASE_PATH=/usr/sbin:$PATH
export PATH=$ORACLE_HOME/bin:$BASE_PATH
export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
export CLASSPATH=$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
alias grid_env='. /home/oracle/grid_env'
alias db_env='. /home/oracle/db_env'
```

4. Reference setEnv.sh at the end of the oracle user's bash profile:

```
echo ". /home/oracle/scripts/setEnv.sh" >> /home/oracle/.bash_profile
```

5. Create the following files in the Oracle home folder:

```
grid_env
export ORACLE_SID=+ASM
export ORACLE_HOME=$GRID_HOME
export PATH=$ORACLE_HOME/bin:$BASE_PATH
export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
db_env
export ORACLE_SID=orcl
export PATH=$ORACLE_HOME/bin:$BASE_PATH
export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib
```

Configuring swap on AWS

1. Create a swapfile:

```
dd if=/dev/zero of=/swapfile bs=1M count=32000
chmod 600 /swapfile
mkswap /swapfile
swapon /swapfile
```

2. Add the following entry to /etc/fstab:

```
/swapfile none swap sw 0 0
```

Installing Oracle Grid 21c

1. Log into the server as oracle.
2. To set the Oracle grid environment, type `grid_env`
3. Change directory to `$ORACLE_HOME`.
4. Extract the Oracle Grid 21c installation files:

```
unzip -oq /media/directory/LINUX.X64_213000_grid_home.zip
```

5. Run this command as the ROOT user to install dependency:

```
rpm -iv /u01/app/21.0.0/grid/cv/rpm/cvuqdisk-1.0.10-1.rpm
```

6. Run the Oracle Grid 21c installer:

```
./gridSetup.sh
```

7. In the Select Installation Option screen, select Install and Configure Grid Infrastructure for a Standalone Server, and click Next.
8. In the Create ASM Disk Group screen, choose the Disk Group Name (DATA), and change redundancy to External.
9. Change Allocation Unit Size to 8 MB.
10. Change Disk Discovery Path to:

```
/dev/oracleasm/disks
```

11. Select the DATA disks, and click Next.
12. In the Specify ASM Password screen, choose Use same password for these accounts, type the passwords for the ASM users, and click Next.
13. At the Management Options screen, click Next.
14. Leave the default Operating System Groups, and click Next.
15. Leave the default installation, and click Next.
16. Leave the default inventory location, and click Next.
17. Under Root script execution, leave the defaults, and click Next.
18. In the Prerequisite Checks screen, make sure that there are no errors.
19. In the Summary screen, verify that everything is correct, and click Finish to install Oracle Grid Infrastructure.
20. During the installation, the installation prompts you to execute two configuration scripts as root. Follow the instructions to run the scripts.
21. At the Finish screen, click Close.

Installing Oracle Database 21c

1. Log into the server as oracle.
2. To set the Oracle grid environment, type `db_env`
3. Change directory to `$ORACLE_HOME`.
4. Extract the Oracle Database 21c installation files:

```
unzip -oq /media/directory/LINUX.X64_213000_db_home.zip
```

5. Run the Oracle Database 21c installer:

```
./runInstaller
```

6. Wait for the GUI installer to load.
7. At Select Configuration Option, select Set Up Software Only, and click Next.
8. On the Database Installation Options screen, click Next.
9. On the Database Edition screen, leave Enterprise Edition selected, and click Next.
10. On the Installation Location screen, click Next.
11. On the Operating System Groups screen, click Next.
12. On the Root script execution screen, click Next.
13. Allow the prerequisite checker to complete.
14. If you need to make any remaining adjustments, follow the instructions on the screen.
15. On the Summary screen, click Install.
16. Once the installer completes, click Close.

Creating and configuring the database

1. To open the Database configuration assistant, type `dbca` and press enter.
2. At the Database Operation screen, select Create Database, and click Next.
3. Under Creation Mode select Advanced configuration, and click Next.
4. At the Deployment Type screen, select General Purpose or Transaction Processing, and click Next.
5. At the Database Identification screen, click Next.
6. At the storage option screen, select Use following for the database storage attributes, and click Next.
7. At the Fast Recovery Option screen, check Specify Fast Recovery Location, and click Next.
8. At the Network Configuration screen, select the listener, and click Next.
9. At the Data Vault Option screen, click Next.
10. At the Configuration Options screen, set the SGA size to 8 GB and the PGA size to 8 GB, and click Next.
11. At the Management Options screen, click Next.
12. At the User Credentials screen, select Use the same administrative password for all accounts, enter and confirm manager as the password, and click Next.
13. At the Creation Options, select Create Database, and click Next.
14. At the summary screen, click Finish.
15. Close the Database Configuration Assistant.
16. Alter the log files and tablespaces as follows:

```
sqlplus '/ as sysdba'  
ALTER USER sys IDENTIFIED BY manager;  
ALTER USER system IDENTIFIED BY manager;  
ALTER DATABASE ADD LOGFILE GROUP 11 ( '/tmp/temp1.log' ) SIZE 50M;  
ALTER DATABASE ADD LOGFILE GROUP 12 ( '/tmp/temp2.log' ) SIZE 50M;  
ALTER SYSTEM SWITCH LOGFILE;  
ALTER SYSTEM SWITCH LOGFILE;  
ALTER SYSTEM CHECKPOINT;  
ALTER DATABASE DROP LOGFILE GROUP 1;  
ALTER DATABASE DROP LOGFILE GROUP 2;  
ALTER DATABASE DROP LOGFILE GROUP 3;  
ALTER SYSTEM SWITCH LOGFILE;  
ALTER SYSTEM SWITCH LOGFILE;  
ALTER SYSTEM CHECKPOINT;  
ALTER SYSTEM SET "_disk_sector_size_override"=TRUE SCOPE=BOTH;
```

```
ALTER DATABASE ADD LOGFILE GROUP 1 ( '+DATA/logfile1.log' ) SIZE 200G BLOCKSIZE 4K;
ALTER DATABASE ADD LOGFILE GROUP 2 ( '+DATA/logfile2.log' ) SIZE 200G BLOCKSIZE 4K;
ALTER DATABASE ADD LOGFILE GROUP 3 ( '+DATA/logfile3.log' ) SIZE 200G BLOCKSIZE 4K;
ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM CHECKPOINT;
ALTER DATABASE DROP LOGFILE GROUP 11;
ALTER DATABASE DROP LOGFILE GROUP 12;
SHUTDOWN;
STARTUP;
HOST rm -f /tmp/temp*.log;
ALTER PLUGGABLE DATABASE orclpdb1 OPEN;
ALTER PLUGGABLE DATABASE orclpdb1 SAVE STATE;
ALTER SESSION SET CONTAINER = orclpdb1;
CREATE BIGFILE TABLESPACE SLOB DATAFILE '+DATA/SLOB.dbf' SIZE 3000G AUTOEXTEND ON NEXT
1G BLOCKSIZE 8K;
```

17. Edit /etc/oratab to change N to Y.

Installing SLOB and populating the database

1. Download the SLOB kit from <http://kevinclonson.net/slob/>.
2. Copy and untar the files to /home/oracle/SLOB.
3. Edit the slob.conf file to match what appears in the Benchmark parameters section below.
4. To switch to the database environment, type db_env
5. Enter SQLPlus:

```
sqlplus '/ as sysdba'
```

6. To start the database, type startup
7. Once the database is up, type exit
8. Start population with ./setup.sh SLOB 24.
9. When the setup is complete, the database is populated.
10. Create the wait_kit:

```
cd wait_kit
make all
cd ..
```

Running SLOB

1. Log in as the Oracle user.
2. Start the database.
3. Navigate to /home/oracle/SLOB.
4. To start the test, type ./runit.sh 24
5. Once the test is finished, collect the results.
6. Repeat the run two more times.

Benchmark parameters

```
#### SLOB 2.5.4.0 slob.conf

UPDATE_PCT=30
SCAN_PCT=0
RUN_TIME=900
WORK_LOOP=0
SCALE=48G
SCAN_TABLE_SZ=10M
WORK_UNIT=64
REDO_STRESS=LITE
LOAD_PARALLEL_DEGREE=1

THREADS_PER_SCHEMA=1

DATABASE_STATISTICS_TYPE=awr # Permitted values: [statspack|awr]

#### Settings for SQL*Net connectivity:
#### Uncomment the following if needed:
#ADMIN_SQLNET_SERVICE="if needed, replace with a valid tnsnames.ora service"
#SQLNET_SERVICE_BASE="if needed, replace with a valid tnsnames.ora service"
#SQLNET_SERVICE_MAX="if needed, replace with a non-zero integer"
#
#### Note: Admin connections to the instance are, by default, made as SYSTEM
#         with the default password of "manager". If you wish to use another
#         privileged account (as would be the case with most DBaaS), then
#         change DBA_PRIV_USER and SYSDBA_PASSWD accordingly.
#### Uncomment the following if needed:
#DBA_PRIV_USER="system"
#SYSDBA_PASSWD="manager"

#### The EXTERNAL_SCRIPT parameter is used by the external script calling feature of runit.sh.
#### Please see SLOB Documentation at https://kevinclonson.net/slob for more information

EXTERNAL_SCRIPT="/home/oracle/SLOB/external_script.sh"

#####
#### Advanced settings:
#### The following are Hot Spot related parameters.
#### By default Hot Spot functionality is disabled (DO_HOTSPOT=FALSE).

DO_HOTSPOT=FALSE
HOTSPOT_MB=8
HOTSPOT_OFFSET_MB=16
HOTSPOT_FREQUENCY=3

#### The following controls operations on Hot Schema
#### Default Value: 0. Default setting disables Hot Schema

HOT_SCHEMA_FREQUENCY=0

#### The following parameters control think time between SLOB
#### operations (SQL Executions).
#### Setting the frequency to 0 disables think time.

THINK_TM_FREQUENCY=0
THINK_TM_MIN=.1
THINK_TM_MAX=.1
```

Read the report at <https://facts.pt/JCLcj4k>



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