



Hewlett Packard
Enterprise

Improving Oracle Database performance with HPE Persistent Memory on HPE ProLiant DL380 Gen9

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Executive summary

The demands of database implementations continue to escalate: faster transaction processing speeds, scalable capacity, and increased flexibility are required to meet the needs of today's business. At the same time, enterprises are looking for cost-effective, open-architecture, industry standard solutions that don't include vendor lock-in or carry the high price tag attached to proprietary solutions.

HPE Persistent Memory products deliver both the performance of memory and the persistence of traditional storage. Customers face increasing pressure to make faster business decisions. The HPE Persistent Memory module delivers outstanding performance to put data to work more quickly in your business. It is ideal for accelerating database and analytics workloads.

This Reference Configuration will demonstrate the ease of configuring HPE 8GB NVDIMM (Non-Volatile DIMM) modules along with the resulting performance gains achievable in an Oracle Database environment. The benefits include significantly improved throughput, better resource utilization, and reduced Oracle licensing costs. Oracle Database throughput increased by a factor of two to four times when using NVDIMMs as compared to 15K RPM SAS drives for Oracle redo logs. In addition, using NVDIMMs for Oracle redo logs was three times more cost effective than an equivalent number of SSDs, and a factor of two to four times faster than 15K RPM SAS drives with only a 40% increase in price.

Target audience: This Hewlett Packard Enterprise white paper is designed for IT professionals and database administrators who use, program, manage, or administer large databases that require high availability and high performance. Specifically, this information is intended for those who evaluate, recommend, or design new high performance architectures to support mission critical databases.

This white paper describes testing completed in May 2016.

Document purpose: The purpose of this document is to describe a Reference Configuration, highlighting recognizable benefits to technical audiences.

Note

This testing made use of the kernel and libraries provided with the HPE Linux® SDK for NVDIMM. The SDK is not for production use. The intent of this paper is to provide a proof point of the performance gains possible when using NVDIMM technology with an Oracle database.

Solution overview

HPE Persistent Memory

To gain a real competitive advantage, you need to enable faster business decisions. The HPE Persistent Memory module delivers outstanding performance to put data to work more quickly in your business. HPE Persistent Memory offerings are not just new hardware technology, but a complete software ecosystem designed to work with today's applications and workloads, including databases and analytics workloads.

The HPE 8GB NVDIMM module is the first offering in the HPE Persistent Memory product category. It delivers the performance of memory with the resiliency you have come to expect from HPE storage technology. Customers can have confidence that business-critical data is safe because HPE utilizes higher endurance DRAM and components that help verify data is moved to non-volatile technology in the event of a power loss.

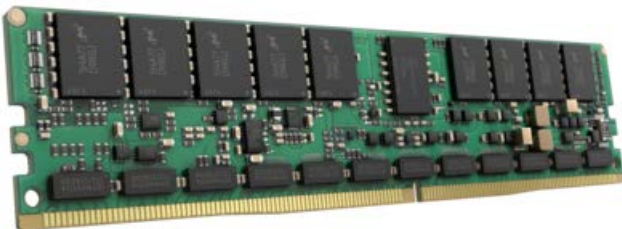


Figure 1. HPE 8GB NVDIMM module

HPE Persistent Memory offers the following features (note that the performance statements included here are based upon HPE internal lab testing that was separate from the Oracle database test results documented in the “Workload results” section of this paper):

Turbo-charged performance delivering up to 4x faster transaction performance

HPE ProLiant DL360 Gen9 and DL380 Gen9 servers equipped with HPE 8GB NVDIMM modules increase performance for write intensive workloads delivering up to 2x+ faster database logging performance¹. The NVDIMM modules are designed to speed customer application workloads, delivering up to 4x+ faster OLTP replication functions² enabling faster workloads.

Technology designed to make your business data resilient

The HPE Persistent Memory modules include a flash component plus an HPE Smart Storage Battery that provides you with a persistent storage capability at memory speeds without the data volatility of memory.³ Active data runs on the DRAM component of NVDIMM which not only provides outstanding performance but also offers greater endurance than traditional storage media.⁴

Solutions designed around your business workloads

HPE Persistent Memory is designed around industry applications and workloads to deliver the performance of memory with the persistence of storage. A complete hardware and software ecosystem provides a comprehensive persistent memory solution for your business.

HPE Linux SDK for NVDIMM

The Linux Software Development Kit is a collection of kernel modules and OS components that can be installed over an existing OS installation to provide base support for Type-N NVDIMM technology. It is meant to allow early adopters and application developers to have access to NVDIMM technology and have an environment with which to experiment and do development. The Linux SDK for NVDIMM-N should only be used on HPE hardware with Non-Volatile Memory (NVDIMM-N) DIMMs installed.

Note

The SDK is not for production use. Its support model is very limited and the software is being provided “as-is” and considered experimental.

Solution components

This white paper provides configuration and performance information for 8GB NVDIMMs in an Oracle 12c Database environment. The tests were run on an HPE ProLiant DL380 Gen9 server running Red Hat® Enterprise Linux 7.2 plus the Linux 4.2 kernel available with the HPE Linux SDK for NVDIMM. The HPE ProLiant DL380 Gen9 server was configured with the following components:

- Two 16-core Intel® Xeon® E5-2683 v4 processors at 2.10 GHz
- 256GB memory (8 x 32GB RDIMMs)
- 16 x HPE 8GB NVDIMM modules
- 24 x 400GB 12G SAS write-intensive SSD drives
- 16 x 450GB 15K RPM SAS drives (swapped out 16 SSDs for SAS testing)

¹Internal HPE lab testing on an HPE ProLiant DL380 Gen9 E5 2600 v4 with HPE 8GB NVDIMM-N, December 2015.

²Internal HPE lab testing on an HPE ProLiant DL380 Gen9 E5 2600 v4 with HPE 8GB NVDIMM-N, December 2015.

³Based on the NVDIMM utilizing NAND Flash as a persistent store and the HPE Smart Storage Battery providing the backup power source to move data from DRAM to NAND Flash.

⁴Endurance comparison based on comparing Program Erase Cycles of DRAM to Program Erase Cycles of NAND Flash. DRAM can have up to 10 trillion more program erase cycles than NAND Flash.

Figure 2 shows the location of the NVDIMMs (outlined in red) and RDIMMS, along with the disk configuration of the HPE ProLiant DL380 Gen9 server.

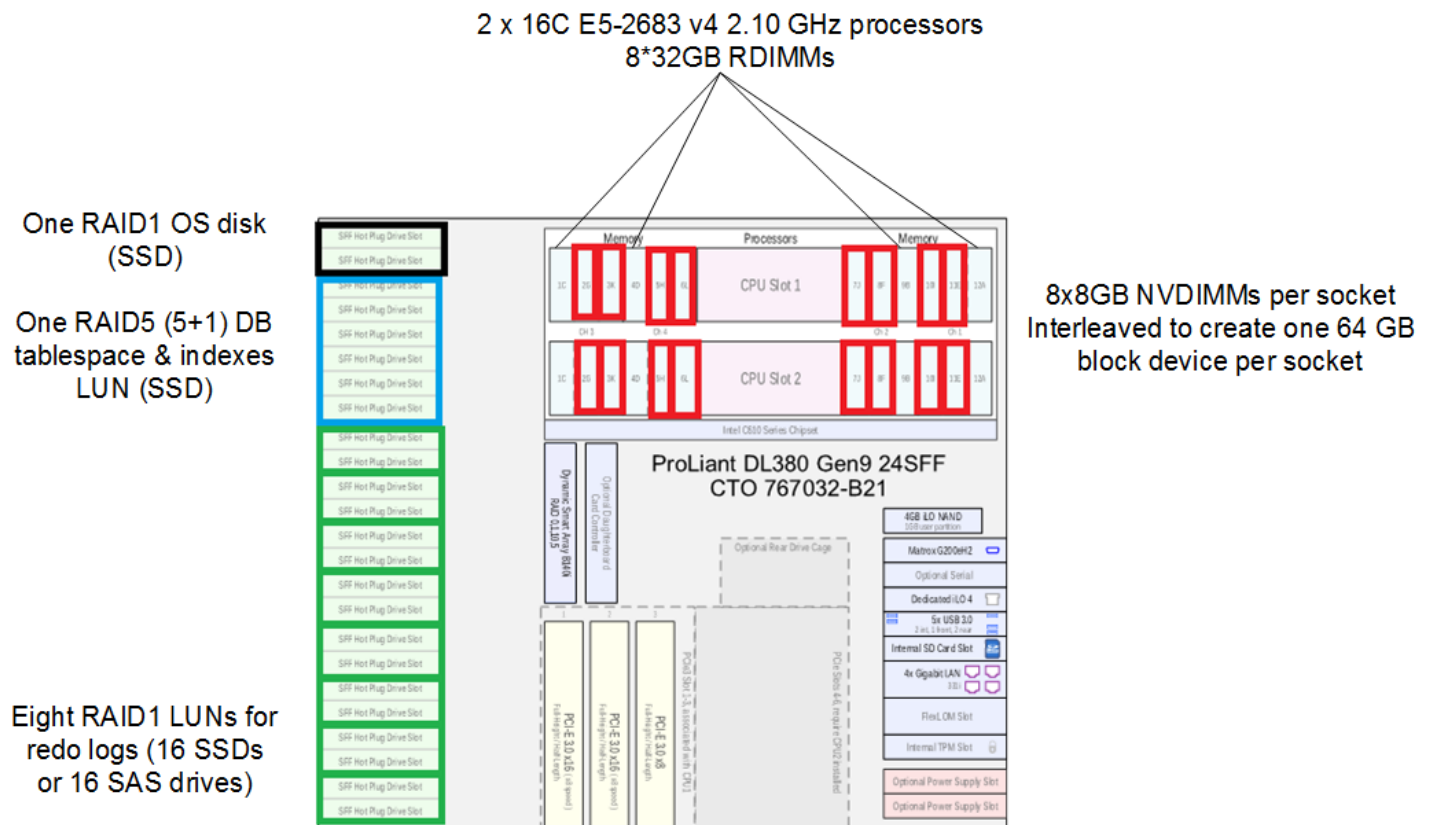


Figure 2. Diagram of memory and disk layout for HPE ProLiant DL380 Gen9 server

Software

- Red Hat Enterprise Linux version 7.2 plus the Linux 4.2 kernel and packages for the NVM library (libpmem and libpmem-devel) provided with the HPE Linux SDK for NVDIMM
- Oracle 12c R1 Enterprise Edition (12.1.0.2)

Best practices and configuration guidance for the Oracle Database solution with NVDIMM

HPE ProLiant DL380 Gen9 BIOS

- Hyper-Threading—Enabled
- Intel Turbo Boost—Enabled
- HPE Power Profile—Maximum Performance

NVDIMM configuration best practices

- The NVDIMMs must be configured according to the population rules outlined in the QuickSpecs and the [HPE 8GB NVDIMM User Guide for HPE ProLiant Gen9 Servers](#). See Appendix B for the configuration used for this testing.
- Balance the total memory capacity across all processors.

- Only RDIMMs can be mixed with NVDIMMs. No other memory types may be used when NVDIMMs are present.
- Interleave the NVDIMM modules (via BIOS settings) to create one block device on each socket. See the [HPE 8GB NVDIMM User Guide for HPE ProLiant Gen9 Servers](#) for interleaving instructions.

Storage configuration best practices

- Database, tablespaces and indexes on SSDs configured in one RAID 5 LUN
- Place redo logs on their own RAID 1 LUNs on the fastest media available

Oracle configuration best practices

For specific Oracle database parameter settings, see Appendix C.

- Disable RHEL automatic NUMA balancing (see Appendix D).
- Disable automatic memory management if applicable.
- Set buffer cache memory size large enough per your implementation to avoid physical reads.
- Create two large redo log file spaces large enough to minimize log file switching and reduce log file waits.⁵
- Create an undo tablespace of 300GB.⁶
- Configure huge pages (see Appendix D) and set Oracle to only use huge pages.

Capacity and sizing

Workload description

The Oracle workload was tested using HammerDB, an open-source tool. The tool implements an OLTP-type workload (60 percent read and 40 percent write) with small I/O sizes of a random nature. The transaction results have been normalized and are used to compare test configurations. Other metrics measured during the workload come from the operating system and/or standard Oracle Automatic Workload Repository (AWR) statistics reports.

The OLTP test, performed on a 1TB database, was both highly CPU and moderately I/O intensive. The environment was tuned for maximum user transactions. After the database was tuned, the transactions were recorded at different connection levels. Because customer workloads vary so much in characteristics, the measurement was made with a focus on maximum transactions.

Oracle Enterprise Database version 12.1.0.2 was used in this test configuration.

The databases used several different Oracle Automatic Storage Management (ASM) disk groups with a combination of RAID 5 and multiple RAID 1 LUNs. The single RAID 5 SSD LUN was used for tablespaces and indexes. Eight RAID 1 LUNs were used for the redo logs for the tests with SAS drives and the tests with SSDs. One NVDIMM 64GB block device was used for each redo log for the persistent memory tests.

We used several different Oracle connection counts for our tests, and found the optimal number to be 125 connections for the NVDIMM configuration.

⁵ It is important that the size and quantity of redo log file spaces be large enough so that a constraint is not encountered when closing one redo log and opening another, such that the new redo log has not had enough time to have been flushed since it was last used.

⁶ This testing used an undo tablespace size of 300GB. The size should be sufficiently large enough that it doesn't cause the queries to throw errors.

Workload results

Three configurations were tested with the Oracle redo logs placed on:

1. 15K RPM SAS drives
2. Write-intensive SSD drives
3. NVDIMM block devices

Figure 3 shows the results of the tests in terms of relative throughput (transactions per minute) achieved with each configuration. The number of Oracle connections is the count of users that drove the test. There was no think time which means that each user represented hundreds of actual users. The results have been normalized, with the throughput for 25 connections with SAS drives set to 100%. All other data points are relative to the initial result.

The data shows that:

- The usage of NVDIMM devices for Oracle redo logs provided 2.3 to 4.6 times better throughput than 15K SAS drives.
- NVDIMMs also provided up to 15% better throughput than write-intensive SSD drives.

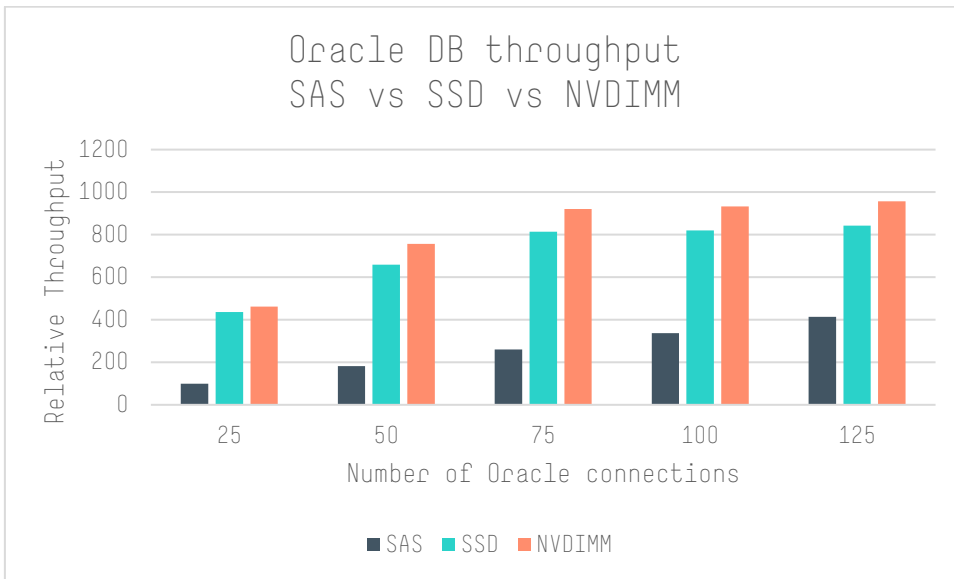


Figure 3. Oracle Database throughput for various disk configurations

The configuration with SAS drives was limited by the log file sync time, and CPU utilization was under 40%. With SSDs, the log file sync time was reduced significantly (by almost a factor of four), but still limited performance at the higher connection counts. With NVDIMMs, the I/O bottleneck was removed and processing power was the limiting factor, with CPU utilization reaching 95%. Figure 4 shows the log file sync time for 125 connections, with NVDIMMs yielding a factor of seven times improvement over SAS drives and a factor of two times over SSDs. It also shows how much CPU utilization improves by removing the I/O bottleneck for the redo logs.

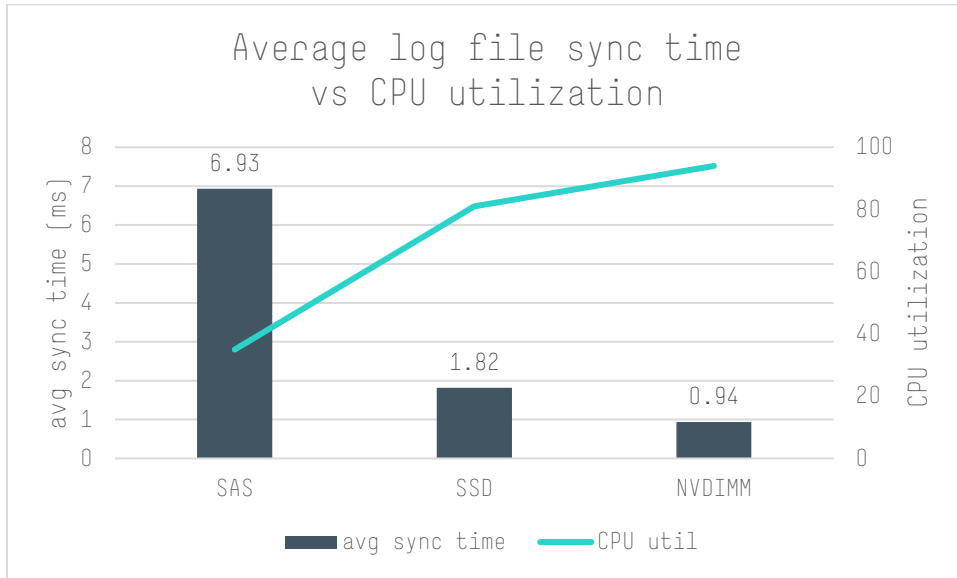


Figure 4. Average log file sync times

The substantial throughput gains achieved by placing the redo logs on NVDIMMs also allows reducing the number of cores required. Tests run with half of the cores in the server disabled⁷ demonstrated that an NVDIMM configuration can outperform a SAS configuration with the original number of cores. Figure 5 shows the throughput achieved with an NVDIMM configuration with only 16 cores (8 cores per processor) as compared to a SAS configuration with 32 cores. Note that because the NVDIMM configuration is CPU bound, reducing the number of cores means that performance peaks at a lower number of Oracle connections, but the throughput at 75 connections is about double that of the SAS drive configuration. This means that usage of NVDIMMs allows Oracle licensing costs to be cut in half while achieving higher throughput than the configuration with 15K RPM SAS drives.

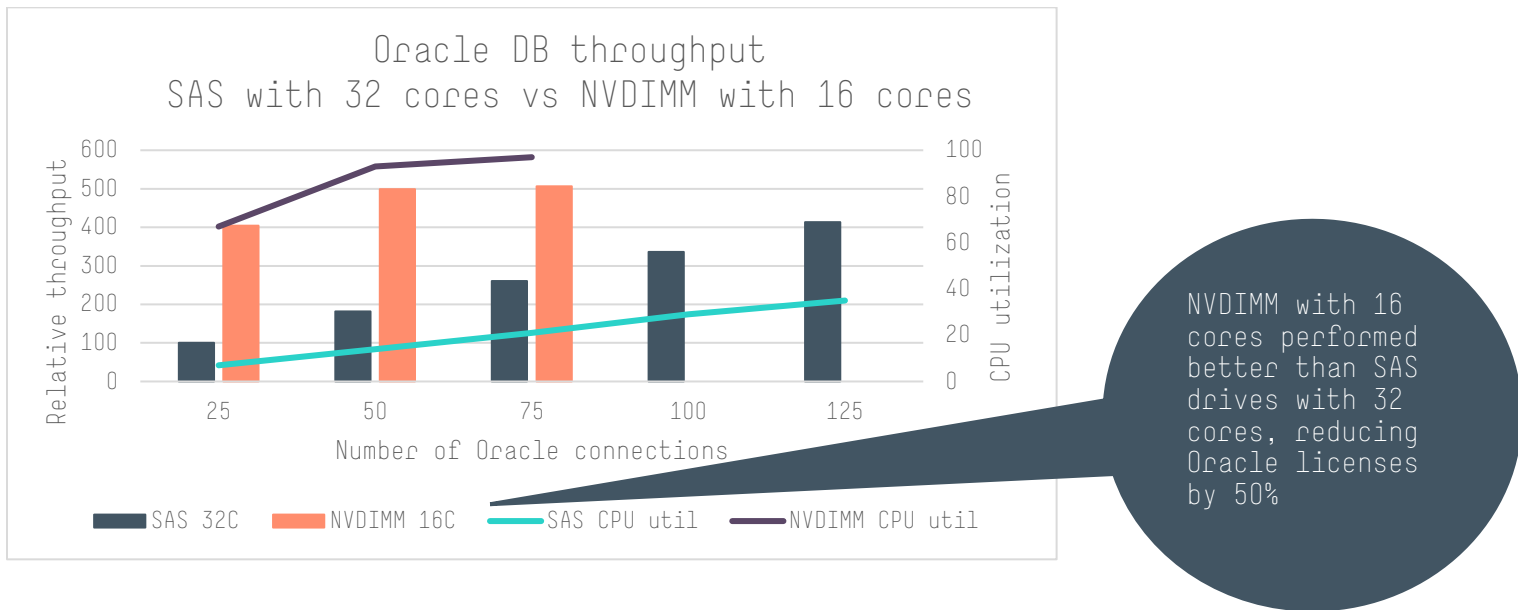


Figure 5. Throughput for SAS configuration with 32 cores versus NVDIMM configuration with 16 cores

In addition, in order to protect against the loss of a redo log on an NVDIMM module, the redo logs may be configured in redundant groups. With sixteen 8GB NVDIMMs, four 32GB redo logs may be configured, with two logs on each of the two /dev/pmem devices. The two redo logs that are placed in the same group should be on separate /dev/pmem devices. See Appendix F for the configuration details. Test results for 125 Oracle connections with the redundant redo logs lowered Oracle throughput (TPM) by only 1% as compared to using two redo logs with no redundancy.

Finally, tests were conducted with 8GB redundant redo logs on four 8GB NVDIMMs to determine the impact of using fewer NVDIMMs. Oracle throughput was within 3% of the results with 16 NVDIMMs, but as expected, the log file switch frequency was higher (every 36 seconds as compared to two minutes for 32GB logs and four minutes for 64GB logs). The more frequent log file switches caused throughput to be more variable across the run, and also caused more variation in CPU utilization. So it is possible to achieve similar throughput with fewer NVDIMMs, but performance may be less predictable.

Analysis and recommendations

The testing has demonstrated the performance benefits of configuring NVDIMM modules for an Oracle Database environment. NVDIMMs can be easily configured to contain Oracle redo log files with up to 64GB of capacity for each persistent memory device on a per socket basis. The following advantages can be achieved with this solution:

Removes the bottleneck of redo log write times.

Improves throughput and resource utilization: Higher transactions per minute and higher CPU utilization were achieved when using NVDIMMs as compared to SAS drives and SSDs.

Lessens the impact of log file switches: Even though log file switches occurred multiple times during the tests, there was no impact on performance due to the fast write time to the NVDIMM devices.

⁷ Note that these tests were run on the same server as the original tests, with half of the cores disabled via a BIOS setting.

Reduces Oracle licensing costs: With NVDIMMs, fewer cores are required to achieve similar or better throughput.

Cost effective solution as compared to SAS drives and SSDs: With a price of \$899 per NVDIMM module⁸, they can be a cost effective means of achieving better performance. For this testing, replacing 15K RPM SAS drives with the same number of NVDIMMs improved performance by a factor of two to four times with only a 40% increase in price (\$637 per SAS drive)⁹. Similarly, using NVDIMMs was three times more cost effective than an equivalent number of write-intensive SSD drives with a list price of \$3050 per drive (sixteen NVDIMMs cost \$14,384 versus \$48,800 for sixteen write-intensive SSDs).¹⁰

Use redundant redo logs to protect against data loss: Create two redo logs on separate persistent memory devices and place them in the same redo log group to provide protection against the loss of a single NVDIMM.

Summary

The availability of HPE 8GB NVDIMM modules significantly improves Oracle Database performance by combining the speed of memory access time with the data persistence of storage. The benefits include improved throughput, increased resource utilization, and reduced Oracle licensing costs. In addition, the cost of HPE 8GB NVDIMM modules make them an attractive solution as compared to SSDs, as well as providing two to four times better throughput as similarly priced 15K RPM SAS drives.

Implementing a proof-of-concept

As a matter of best practice for all deployments, HPE recommends implementing a proof-of-concept using a test environment that matches as closely as possible the planned production environment. In this way, appropriate performance and scalability characterizations can be obtained. For help with a proof-of-concept, contact an HPE Services representative (hpe.com/us/en/services/consulting.html) or your HPE partner.

⁸ Price as of May 26, 2016 for HPE 8GB NVDIMM <http://www8.hp.com/us/en/products/server-memory/product-detail.html?oid=1008830324>

⁹ Price as of May 26, 2016 for HPE 450GB 12G SAS 15K RPM SFF drive <http://www8.hp.com/us/en/products/oas/product-detail.html?oid=6826121>

¹⁰ Price as of May 26, 2016 for HPE 400GB 12G SAS write intensive SFF Solid State Drive <http://www8.hp.com/us/en/products/oas/product-detail.html?oid=7605795>

Appendix A: Bill of materials

Note

Part numbers are at time of testing and subject to change. The bill of materials does not include complete support options or rack and power requirements. If you have questions regarding ordering, please consult with your HPE Reseller or HPE Sales Representative for more details. hpe.com/us/en/services/consulting.html

Table 1. Bill of materials

| QTY | PART NUMBER | DESCRIPTION |
|---------------------------------------|-------------|--|
| HPE ProLiant DL380 Gen9 server | | |
| 1 | 767032-B21 | HPE DL380 Gen9 24SFF CTO Server |
| 1 | 817953-L21 | HPE DL380 Gen9 E5-2683v4 FIO Kit |
| 1 | 817953-B21 | HPE DL380 Gen9 E5-2683v4 Kit |
| 8 | 728629-B21 | HPE 32GB 2Rx4 PC4-2133P-R Kit |
| 16 | 782692-B21 | HPE 8GB NVDIMM Single Rank x4 DDR4-2133 Module |
| 24 | 802582-B21 | HPE 400GB 12G SAS WI 2.5in SC SSD |
| 16 | 759210-B21 | HPE 450GB 12G SAS 15K RPM SFF Hard Drive ¹¹ |
| 1 | 761872-B21 | HPE Smart Array P440/4G FIO Controller |
| 1 | 727250-B21 | HPE 12Gb DL380 Gen9 SAS Expander Card |
| 1 | 779799-B21 | HPE Ethernet 10Gb 2P 546FLR-SFP+ Adptr |
| 1 | 733660-B21 | HPE 2U SFF Easy Install Rail Kit |
| 2 | 720478-B21 | HPE 500W FS Plat Ht Plg Pwr Supply Kit |

¹¹ Sixteen SSDs were removed in order to use the SAS hard drives

Appendix B: Memory configuration

Table 2 shows the memory configuration for the HPE ProLiant DL380 Gen9 server, including which slots were populated with NVDIMMs and which ones had RDIMMs. For the memory population rules, see the QuickSpecs and the [HPE 8GB NVDIMM User Guide for HPE ProLiant Gen9 Servers](#).

Table 2. Memory configuration

Memory Details (show empty sockets)

| Memory Location | Socket | Status | HPE Memory | Part Number | Type | Size | Maximum Frequency | Minimum Voltage | Ranks | Technology |
|-----------------|--------|--------------|-----------------|-------------|-----------|----------|-------------------|-----------------|-------|------------|
| Processor 1 | 1 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 1 | 2 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 3 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 4 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 1 | 5 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 6 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 7 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 8 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 9 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 1 | 10 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 11 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 1 | 12 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 2 | 1 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 2 | 2 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 3 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 4 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 2 | 5 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 6 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 7 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 8 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 9 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |
| Processor 2 | 10 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 11 | Good, In Use | HPE SmartMemory | N/A | DIMM DDR4 | 8192 MB | 2133 MHz | 1.2 V | 1 | R-NVDIMM |
| Processor 2 | 12 | Good, In Use | HPE SmartMemory | 752370-091 | DIMM DDR4 | 32768 MB | 2133 MHz | 1.2 V | 2 | RDIMM |

Appendix C: Oracle configuration parameters

```
open_cursors=3000
pga_aggregate_target=51546M
processes=3000
result_cache_max_size=794304K
sga_target=155136M
_high_priority_processes='VKTM*|LG*'
lock_sga=TRUE
use_large_pages='ONLY'
_max_outstanding_log_writes=4
```

Appendix D: Linux kernel configuration

```
kernel.sem = 250 32000 100 128
kernel.shmall = 4294967295
kernel.shmmax = 332859965440
fs.file-max = 6815744
kernel.shmmni = 4096
fs.aio-max-nr = 1048576
net.ipv4.ip_local_port_range = 9000 65500
net.core.rmem_default = 262144
net.core.rmem_max = 4194304
net.core.wmem_default = 262144
net.core.wmem_max = 1048586
vm.nr_hugepages = 77572
vm.hugetlb_shm_group = 1002
kernel.numa_balancing=0
```

Notes

1. The `vm.nr_hugepages` is dependent on the amount of memory installed in the server. We had 256GB in the HPE ProLiant DL380 Gen9, so we set it to 77572.
 2. For RHEL 7, automatic NUMA balancing should be disabled (by setting `kernel.numa_balancing=0`) for optimal Oracle performance. This resulted in a significant performance improvement for our testing.
-

Appendix E: udev rules

A udev rules file `/etc/udev/rules.d/99-oracleasm.rules` was created to set the required ownership of the Oracle ASM LUNs:

```
ACTION=="add|change", KERNEL=="sdb",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdc",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdd",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sde",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdf",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdg",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdh",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdi",OWNER="oracle",GROUP="dba",MODE="0660"
ACTION=="add|change", KERNEL=="sdj",OWNER="oracle",GROUP="dba",MODE="0660"
ENV{DM_NAME}=="data-lvol0", OWNER:="oracle", GROUP:="oinstall", MODE:="660"
ENV{DM_NAME}=="redo-lvol0", OWNER:="oracle", GROUP:="oinstall", MODE:="660"
ENV{DM_NAME}=="redo--pmem0-lvol0", OWNER:="oracle", GROUP:="oinstall", MODE:="660"
ENV{DM_NAME}=="redo--pmem1-lvol0", OWNER:="oracle", GROUP:="oinstall", MODE:="660"
```

Appendix F: Create redundant redo logs

The commands used to create two redo log groups, with two 32GB redo logs on each persistent memory device, are shown below. Note that within one redo log group, there are two redo log files, with each one residing on a separate ASM volume on different persistent memory devices (REDO_PMEM0 and REDO_PMEM1).

```
SQL> alter database add logfile group 20 ('+REDO_PMEM0', '+REDO_PMEM1') size 31950M;
```

Database altered.

```
SQL> alter database add logfile group 21 ('+REDO_PMEM0', '+REDO_PMEM1') size 31950M;
```

Database altered.

```
SQL> select group#,member from v$logfile;
```

```

      20
+REDO_PMEM0/ORADL380/ONLINELOG/group_20.256.915105841

      20
+REDO_PMEM1/ORADL380/ONLINELOG/group_20.256.916653663

      21
+REDO_PMEM0/ORADL380/ONLINELOG/group_21.257.916653823

      21
+REDO_PMEM1/ORADL380/ONLINELOG/group_21.257.915105921
```

Resources and additional links

HPE & Oracle Alliance

<http://h22168.www2.hp.com/us/en/partners/oracle/>

HPE & Oracle Alliance Technical page

<http://h17007.www1.hp.com/us/en/enterprise/converged-infrastructure/info-library/index.aspx?app=oracle>

HPE ProLiant DL380 Gen9 server

hp.com/servers/dl380

HPE Persistent Memory

hp.com/servers/persistentmemory

HPE Linux SDK for NVDIMM

<http://linux.hp.com/nvdimm/>

HPE 8GB NVDIMM User Guide for HPE ProLiant Gen9 Servers

hp.com/info/NVDIMM-docs

HPE Reference Architectures

hp.com/info/ra

HPE Technology Consulting Services

hp.com/us/en/services/consulting.html

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