NVDIMM-N Tested to the SNIA SSD Performance Test Specification DIRTH Test

Eden Kim, CEO Calypso Systems, Inc.
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Abstract

Test Engineers & Marketing Managers responsible for SSD test, deployment and qualification.

- This session will appeal to Data Center Managers, Development Managers, and those that are seeking an **advanced understanding of the SNIA's Solid State Storage Performance Test Specification (PTS) DIRTH tests**
- DIRTH tests are Demand Intensity Response Time Histogram tests which profile a storage device for **varying Demand Intensity to assess its impact on IOPS, Response Times and Quality of Service**
- The session will investigate Demand Intensity / Outstanding IOs and Confidence Level Plots / Response Time Histograms for a Random 4K 100% Read and 100% Write workload
- The audience learn **how to evaluate IOPS and Response Time Saturation & how to conduct a Response Time Confidence Level Sensitivity Analysis**
- A **case study** will be presented applying the DIRTH test to a Random 4K 100% Read and 100% Write workload
Agenda

• What Factors Impact SSD Performance?
• What is a DIRTH Test?
• What are NVDIMM-Ns?
• DIRTH Test - *SATA SSD Example*
  – Basic Test Flow – Considerations for NAND Flash and NVDIMM-N
  – Examples of Enterprise SSD DIRTH Data Plots
• Case Study – *NVDIMM-N DIRTH*
  – NVDIMM-N 4x 8GB Module 32GB Device
  – DIRTH Random 4K 100% Write & 100% Read workloads
  – Examination of IOPS and Response Times
Learning Objectives

• What is:
  – Demand Variation
  – Demand Intensity
  – A Confidence Level Plot
  – A Response Time Histogram

• How to:
  – Evaluate IOPS and Response Time Saturation
  – Do a Sensitivity Analysis of Confidence Levels
What Factors Impact NAND Flash SSD Performance?

Write History

How much and what kind of data has been written to the drive?
What was the immediately preceding workload?

Workload

What stimuli is being applied to the drive?
Access Pattern, Data Pattern, Number of IO streams, Data Transfer Sizes, RW Mixes, etc.

Demand Intensity

What is the application environment?
How many Users and Jobs?
How many parallel devices?
What is a DIRTTH test?

DIRTH = Demand Intensity Response Time Histogram test

What is the objective of a DIRTTH test?

To assess the Response Time and IOPS saturation levels of an SSD when varying the Demand Intensity (or Outstanding IOs) for a given workload or IO stream(s)

What is the value of using a DIRTTH test?

It allows you to profile an SSD to see how many users and jobs are needed to:
1. Obtain the maximum IOPS rate
2. See where there is an increase in response times without a corresponding increase in IOPS
3. Understand the optimal number of devices to deploy for a given application environment
What are NVDIMM-Ns?

What is an NVDIMM-N?

NVDIMM-N = Non Volatile Dual In-line Memory Module – Type N
Type N = DRAM that is memory mapped to be used as persistent memory, byte addressable or block IO that uses NAND SSD as non volatile memory back up during a power loss event

How is it used as a storage device?

It can be used as a block IO device, file system or byte addressable load & store
Here, we use it as a block IO device using the Intel open source block IO driver

Are there other types of NVDIMMs?

RDIMMs are standard volatile RAM memory modules
NVDIMM-F use NAND SSDs as storage directly in the DIMM channel (not as backup)
NVDIMM-P are hybrid storage devices under development
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<th>Purpose / Description</th>
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<th>NVDIMM-N</th>
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<td>PURGE</td>
<td>Re-set cells/tables</td>
<td>Clear Write History</td>
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<td>Workload Independent Pre condition (WIPC)</td>
<td>Write Twice User Capacity in SEQ 128K</td>
<td>De Fragment / Linearize tables</td>
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<td>Determine RT Quality of Service (QoS)</td>
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DIRTH TEST
SAMPLE PLOTS

Enterprise SATA SSD
Test Flow & DIRTH Test Plots
1. WDPC Pre Writes to Steady State
2. Workload OIO Loops to Steady State
3. Demand Variation
4. Demand Intensity
5. Confidence Level RT Histogram – Max IOPS

6. Confidence Level Plot Compare (CLPC)

7. IOPS & ART v Total OIO

8. IOPS & CPU Usage v Total OIO
Testing NVDIMM-N to the PTS DIRTH test

Case study
4 x 8GB modules – 32GB Device
RND 4K Read & Write workloads
Test Plan

1. Follow PTS-E v 1.1 DIRTH tests (*Performance Test Specification Enterprise*)
2. Run RND 4K RW100 and RW0 workloads (*100% Read & 100% Write*)
3. Set OIO range from T256/Q64 to T8/Q1 (*T/Q = Thread Count/Queue Depth*)
4. Evaluate Demand Intensity and Demand Variation (*DI and DV*)
5. Plot Histograms, Confidence Level Plots and OIO Saturation
Test Set Up

Hardware Platform

- Motherboard: SuperMicro X10DRI
- Operating System: CentOS 7.0
- Kernel: 4.0.0-rc6+
- CPUs: Dual 8 core E5 2670 v3 CPUs
- RAM: 16GB DDR4 RAM
- NVDIMMs: 4 x 8GB NVDIMM-N Modules
- Test Software: CTS BE ver 1.9.250

Software Platform – CTS 6.5

- Test Software: CTS FE ver 1.22.9
- OS: Windows 7 Pro
NVDIMM-N Set Up

NVDIMM Modules

- DDR4 4x 8GB
- 2133 Mhz clocked down to 1866 Mhz
- Write Back Enabled
- NUMA Enabled
- Non Interleaved
- Intel Open Source Development block IO driver
- Version: 4.0.0-rc6+ SMP
NVDIMM-Ns Tested to SNIA PTS SSD Performance Test Specification DIRTH Test
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9. Demand Variation – RND 4K 100% Writes

10. Demand Variation – RND 4K 100% Reads

11. Demand Intensity – RND 4K 100% Writes

12. Demand Intensity – RND 4K 100% Reads
Data Analysis – DV and DI

- NVDIMM-N 32GB IOPS & RTs vary with changing OIO
- DV shows IOPS range is substantially symmetric for 100% Reads (Rs) and 100% Writes (Ws)
- DI shows OIO saturation point (knee) for both Rs & Ws
- Note: TC/QD loop range increased from SSD T32/Q32 – T1/Q1 to NVDIMM-N T256/Q64 – T8/Q1 (to provide sufficient DI)
NVDIMM-N – Response Time Confidence Level Histograms

13. Response Time Histogram – Min IOPS point WRITES

14. Response Time Histogram – Min IOPS point READS

15. Response Time Histogram – Mid IOPS point WRITES

16. Response Time Histogram – Mid IOPS point READS
Data Analysis - Histograms

- Min & Mid Confidence Level Response Time Histograms shown
- Response Time Confidence levels are shown in vertical bars
- ART, 3 9s, 4 9s and 5 9s are colored bars
- Note: Max RT in Mid Histogram Reads of 3,370.61 mS
NVDIMM-N – Response Time Confidence Level Plot Compare

17. Response Time Histogram – Max IOPS point WRITES

18. Response Time Histogram – Max IOPS point READS

19. Confidence Level Plot Compare - WRITES

20. Confidence Level Plot Compare - READS

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Data Analysis – QoS (Quality of Service)

- Max Confidence Level Response Time Histograms shown
- Confidence Level Plot Compare shows 4 OIO points
- Min, Mid, Max and Max Prime OIO and IOPS & RTs
- Note: Max Prime shows maximum IOPS w/o regard to RTs
NVDIMM-N – Total OIO v IOPS/CPU Usage & ART

21. Total OIO x IOPS & ART WRITES

22. Total OIO x IOPS & ART READS

23. Total OIO x IOPS & CPU Usage % - WRITES

24. Total OIO x IOPS & CPU Usage % - READS
Data Analysis - RTs and CPU Usage %

- Plots show Total OIO x IOPS & CPU Usage %
- Lowest OIO shows reasonable IOPS, ART and CPU Usage %
- Higher OIO shows higher IOPS but at higher ART & CPU Usage %
- Note: Compare plot 24 NVDIMM-N CPU Usage % to plot 8 SSD CPU Usage %
Findings

• Intel Block IO driver is a development driver
• Driver & settings are not optimized for block IO
• High RT can result from Cache Flush, Memory Syncs, QPI lane accesses, NVDIMM Module configuration or other settings
• Performance will differ using File System or Memory Map
Take Aways

• *DIRTH* tests present IOPS and OIO saturation points

• *Total OIO* shows CPU and RT saturation

• *Use the DIRTH test to determine the optimal driver, settings & device configurations for your application & deployment*
The SNIA Education Committee thanks the following individuals for their contributions to this Tutorial.

**Authorship History**
Eden Kim, August 18, 2015
Updates: September 24, 2015

**Additional Contributors**
Jeff Chang, AgigA Tech
Arthur Sanio, Smart Modular
Raghu Kulkarni, Viking Technology

*Please send any questions or comments regarding this SNIA Tutorial to tracktutorials@snia.org*