Synthetic Enterprise Application Workloads

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Calypso Systems, Inc.
Synthetic Enterprise Application Workloads

• What are they?
• Why are they used?
• How do I use them?
• What are some examples?
• Case Study
  – Two 2014 released SATA Enterprise class SSDs
  – OLTP workload tested to saturation
  – Examination of IOPS and Response Times
Learning Objectives

• What are:
  – Demand Intensity Levels & Outstanding IOs
  – Confidence Level Plots & Response Time Histograms
  – Synthetic Application workloads

• How to:
  – Evaluate IOPS and Response Time Saturation
  – Do a Sensitivity Analysis of Confidence Levels
  – Build a test template for synthetic workloads
Synthetic Enterprise Application Workloads

WHAT ARE THEY?
Enterprise Applications

Applications common in the Enterprise include:

- OLTP (On Line Transaction Processing)
- OLAP (On Line Analytical Processing)
- VOD (Video on demand)
- OS Paging
- Webserver / Exchange mail
- Logging (web server, SQL server logs)
- DSS (Decision Support Systems)
- Medical Imaging
Enterprise Application Workloads

Test Profile – IOPS & RT levels of different synthetic workloads

Composite Enterprise Workloads

IOPS level

Pre-conditioning Workloads

Composite Enterprise Workloads Response Times

Different workloads apply different access patterns to the SSD.

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Application Workloads are generated in user space and traverse the IO stack to the SSD.

Testing wants to measure workloads as close to the SSD as possible (Block IO level).
Workloads are described by Access Patterns

<table>
<thead>
<tr>
<th>Degree of Randomness</th>
<th>Data Transfer Size</th>
<th>Read Write Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random or Sequential</td>
<td>Block Size</td>
<td>Read/Write Mix</td>
</tr>
</tbody>
</table>

Workloads are a series of Access Patterns over an observation period

Examples of Access Patterns for different workloads:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RND</td>
<td>4KiB</td>
<td>RW0</td>
</tr>
<tr>
<td>RND</td>
<td>8KiB</td>
<td>RW65</td>
</tr>
<tr>
<td>SEQ</td>
<td>128KiB</td>
<td>RW90</td>
</tr>
<tr>
<td>SR75</td>
<td>64KiB</td>
<td>RW95</td>
</tr>
<tr>
<td>SR25</td>
<td>128KiB</td>
<td>RW05</td>
</tr>
</tbody>
</table>

Workloads can be:

*Monotonic or Composite stream of Accesses*

*Synthetic or Real World workloads*
Real-world Workloads

IO Trace Captures are specific to the system
Contain many many streams of different access patterns
Synthetic Workloads – Known & Repeatable Stimulus for Standardized Test

Four “corner case” workloads applied to a single SSD - Bandwidth

**TAKE AWAY**
Standard synthetic workloads can be used with all testers and applied to all SSDs.
Synthetic Enterprise Application Workloads

WHY ARE THEY USED?
Synthetic Workloads allow SSD Comparison

Real World (Trace based / IO based) Workloads:
- Are specific only to the system on which it was captured (*Apples to Oranges*)
- Difficult to account for “idle times”
- Have a large number of streams (can be 50 or more discrete access patterns)

Synthetic Workloads:
- Are repeatable and of known content (*Apples to Apples*)
- Can be standardized for testing on a few known patterns
- *Provide a basis for SSD Performance comparison*
### Synthetic Enterprise Application Workloads

**WHAT ARE SOME EXAMPLES?**

<table>
<thead>
<tr>
<th></th>
<th>Size</th>
<th>Read</th>
<th>Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webserver 8K</td>
<td>8 KiB</td>
<td>75:25</td>
<td>95:5</td>
</tr>
<tr>
<td>Webserver 64K</td>
<td>64 KiB</td>
<td>75:25</td>
<td>95:5</td>
</tr>
<tr>
<td>Exchange Mail 4K</td>
<td>4 KiB</td>
<td>100:0</td>
<td>67:33</td>
</tr>
<tr>
<td>Exchange Mail 64K</td>
<td>64 KiB</td>
<td>100:0</td>
<td>67:33</td>
</tr>
<tr>
<td>Web Server Logs</td>
<td>8 KiB</td>
<td>0:100</td>
<td>0:100</td>
</tr>
<tr>
<td>File Servers</td>
<td>8 KiB</td>
<td>75:25</td>
<td>90:10</td>
</tr>
<tr>
<td>DB OLTP</td>
<td>8 KiB</td>
<td>100:0</td>
<td>70:30</td>
</tr>
<tr>
<td>SQL Logs</td>
<td>64 KiB</td>
<td>0:100</td>
<td>0:100</td>
</tr>
<tr>
<td>Media Streaming</td>
<td>64 KiB</td>
<td>0:100</td>
<td>98:2</td>
</tr>
<tr>
<td>Archive</td>
<td>2048 KiB</td>
<td>95:5</td>
<td>55:45</td>
</tr>
</tbody>
</table>
Examples of Synthetic Enterprise Application Workloads

<table>
<thead>
<tr>
<th>Application Name</th>
<th>General Description</th>
<th>Example Access Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLTP VDI</td>
<td>Small Block Mixed RND Workload</td>
<td>RND 4KiB RW65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RND 8KiB RW67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RND 8KiB RW70</td>
</tr>
<tr>
<td>VOD</td>
<td>Video Edge Server large block SEQ</td>
<td>SEQ 128KiB RW90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RND 128KiB RW90</td>
</tr>
<tr>
<td>Webserver/MS Exchange Mail</td>
<td>Application page sizes of 64K</td>
<td>SEQ25 64KiB RW95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RND 64KiB RW0</td>
</tr>
<tr>
<td>Webserver Logs</td>
<td>Logging workloads for RDBMS</td>
<td>SEQ 8KiB RW0</td>
</tr>
<tr>
<td>Decision Support Service (DSS)</td>
<td>Heavily Indexed large table structures for real time access</td>
<td>RND 64KiB RW100</td>
</tr>
<tr>
<td>OS Paging Medical Streaming Medical Imaging</td>
<td>OS data requests from storage in medium block SEQ transfers</td>
<td>SEQ 64KiB RW90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SEQ 64KiB RW98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SEQ 1,024KiB RW05</td>
</tr>
</tbody>
</table>

Workloads can be a single access pattern or a composite of many different access patterns.
CASE STUDY

Synthetic Enterprise Application Workloads
Objectives

• Define a procedure to test and measure Synthetic application workloads
• Use SNIA PTS test methodologies for Pre-conditioning & Steady State
• Isolate variables for IOPS & RT Confidence measurement
• Create a template to modify / substitute synthetic workloads of interest
Test Plan

1. Apply synthetic OLTP db workload
2. Run workload to steady state
3. Run Demand Intensity (DI) Sensitivity workload loops
4. Measure IOPS, ART & MRT at each QD for each loop
5. Plot Confidence Level Histograms for each OIO point
6. Determine IOPS & Response Time Saturation point(s)
7. Compare OIO “sweet spots” for different DI workload loops
Test Set Up

Hardware Platform – RTP 3.0

– Calypso Reference Test Platform
– CentOS 6.5
– Calypso CTS BE ver 1.9.184
– Intel Gen3 E5 based motherboard
– Dual S2697W 3.1Ghz 8 core cpu’s
– 12Gb/s LSI 9300 HBA

Software Platform – CTS 6.5

– Calypso CTS FE ver 1.18.11
– Windows 7 Pro
Test Flow

1. **PURGE** (Security Erase)

2. **Settings**: Data Pattern=RND; LBA Range=(0,100)

3. **Pre-condition** – WIPC 2x user capacity SEQ 128KiB RW0; T1Q32

4. **Run Workload Dependent PC** – RND 8KiB RW65; T4Q8

5. **Run to Steady State**
   - 5 consecutive one minute Rounds
   - Each Round separated by 29 min of WDPC pre-writes
   - Least squares linear fit no greater than 20% data excursion nor exceeding a 10% slope

6. **Set Restricted LBA zones**
   - 50% of the IOs to the first 5% of the LBAs
   - 30% of the IOs to the next 15% of the LBAs
   - 20% of the IOs to the last 80% of the LBAs

7. **Run Workload Segment loops** w/ varying OIO:
   - Thee TC loops per drive: T2, T4, T8 or T4, T8, T16
   - Step QD 2,4,8,16,32

8. **Plot IOPS, ART, MRT** at each OIO

9. **Plot Confidence Level Histogram & RT Ceiling** for each OIO

10. **Compare Optimal OIO** sweet spots between different TC workload segment loops
What are Confidence Levels?

Response Time (RT) Histograms
Confidence Level Plots (CLP)
CLP Comparison Plots (CLPC)
Confidence Levels – Quality of Service (“Q o S”)

<table>
<thead>
<tr>
<th>IO Rate Per Sec</th>
<th>Measurement Period</th>
<th>Total IOs</th>
<th>% Confidence Level</th>
<th>Q o S No. “9’s”</th>
<th>No. of Dropped IOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Minute Measurement Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>One Minute</td>
<td>600,000</td>
<td>99.999%</td>
<td>5 9’s</td>
<td>6</td>
</tr>
<tr>
<td>10,000</td>
<td>One Minute</td>
<td>600,000</td>
<td>99.99%</td>
<td>4 9’s</td>
<td>60</td>
</tr>
<tr>
<td>10,000</td>
<td>One Minute</td>
<td>600,000</td>
<td>99.9%</td>
<td>3 9’s</td>
<td>600</td>
</tr>
<tr>
<td>Ten Minute Measurement Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>Ten Minutes</td>
<td>6,000,000</td>
<td>99.999%</td>
<td>5 9’s</td>
<td>60</td>
</tr>
<tr>
<td>10,000</td>
<td>Ten Minutes</td>
<td>6,000,000</td>
<td>99.99%</td>
<td>4 9’s</td>
<td>600</td>
</tr>
<tr>
<td>10,000</td>
<td>Ten Minutes</td>
<td>6,000,000</td>
<td>99.9%</td>
<td>3 9’s</td>
<td>6,000</td>
</tr>
</tbody>
</table>

“Five 9’s” = 99.999% or 99,999 of 100,000 events
Response Time Histogram with Confidence Level Percentages

SSD A OLTP: T4Q16, IOPS=43,617, 341 MB/s, MRT=15.615 ms

ART 99.9% 99.99% 99.999%
MRT 99%

Take Away: Figures of Merit are the Response Time Bars that show cumulative IOs at a given ms response time.
Histogram Compare Plot with RT Ceiling

SSD A T4 - RT Histogram Comparison - Confidence Levels & RT Ceiling Plot

- ART
- 99%
- 99.9%
- 99.99%
- 99.999%
- MRT
- RT Ceiling = 15.0
- IOPS

Response Time (mSec)

DB OLTP T4/Q2  DB OLTP T4/Q4  DB OLTP T4/Q8  DB OLTP T4/Q16  DB OLTP T4/Q32

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OLTP Saturation Test with Demand Intensity (DI) Sensitivity Analysis

Workload loops with Varying Demand Intensity

SSD A: T4, T8, T16
SSD B: T2, T4, T8

Find your operating Sweet Spot!
800 GB Enterprise class 2.5” SATA

SSD A
SSD A – Test Profile: IOPS v Time
Workload Segments T4, T8, T16

DI Sensitivity test measures workload segments at increasing TC
SSD A: SEQ128K PC

![Graph showing performance metrics for SSD A: SEQ128K PC]
SSD A: WDPC & Steady State

![Graph showing SSD A performance metrics](image-url)
SSD A T4: QD Histogram Compare

T4 is not enough OIO to Saturate.

No IOPS Saturation
More OIO needed

Response Time Saturation

RT Ceiling

IOPS

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SSD A **T8**: QD Histogram Compare

**TAKE AWAY**

IOPS Saturation begins at T8Q16 RT Saturation at 99.999% T8Q32.

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**SSD A T8 - RT Histogram Comparison - Confidence Levels & RT Ceiling Plot**

- **IOPS & RT Sweet Spot**: 36,827
- **IOPS Saturation appears**: 41,328
- **RT Ceiling = 15.0**: 43,713
- **Response Time Saturation**: 45,530 and 45,407

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**Response Time (mSec)**

- **RT Ceiling**: 30,000 mSec

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**IOPS**

- **DB OLTP T8/Q2**: 2.78
- **DB OLTP T8/Q4**: 5.34
- **DB OLTP T8/Q8**: 8.76
- **DB OLTP T8/Q16**: 11.9
- **DB OLTP T8/Q32**: 11.9

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SSD A **T16**: QD Histogram Compare

**TAKE AWAY**
SSD at T16 fully Saturates. Note increase in RT scale and decrease in IOPS.
200 GB Enterprise class 2.5” SATA

SSD B
SSD B – Test Profile: IOPS v Time
Workload Segments T2, T4, T8

TAKE AWAY
SSD B DI Sensitivity is lower and tests will set QIO at T2, T4 and T8.
SSD B T2: QD Histogram Compare

SSD B OIO T2 shows saturation. Note low OIO at T2Q2.

TAKE AWAY

- SSD B OIO T2 shows saturation. Note low OIO at T2Q2.
SSD B **T4**: QD Histogram Compare

**Take Away**

SSD B at T4 shows saturation. Note QIO Sweet Spot T4Q8.

**SSD B T4 - RT Histogram Comparison - Confidence Levels & RT Ceiling Plot**

- ART
- 99%
- 99.9%
- 99.99%
- 99.999%
- MRT
- RT Ceiling = 15.0
- IOPS

- IOPS & RT T4 Sweet Spot
- RT Ceiling
SSD B **T8**: QD Histogram Compare

**Take Away:**
SSD B at T8 verifies saturation. Note T8 Sweet Spot at T8Q4.
Findings

What are the optimal operating point(s)?
SSD A: Histogram Compare T4 T8 T16

SSD A - OIO Compare Optimal IOPS & Response Time Confidence

Response Time (mSec)

SSD A T4: DB OLTP T4Q4
SSD A T8: DB OLTP T8Q8
SSD A T16: DB OLTP T16Q2

RT Ceiling

37,377
43,713
41,006

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SSD B: Histogram Compare T2 T4 T8

SSD B - OIO Compare Optimal IOPS & Response Time Confidence

Response Time (mSec)

IOPS

RT Ceiling

SSD B T2: DB OLTP T2Q16
SSD B T4: DB OLTP T4Q8
SSD B T8: DB OLTP T8Q4

SSD B 200 GB optimal OIO at any combination of OIO=32: T2Q16, T4Q8 or T8Q4.
Conclusion

- Application(s) may require low or high OIO
- Drive Design may emphasize low or high OIO
- Drives may be designed for specific (different) workloads

**Understanding your SSD’s deterministic behavior helps SSD & system design optimization.**

**Know the “cost” of more IOPS in terms of Response Times.**
Thank You

-Calypso Systems, Inc.

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