Benchmarking The New Storage Technologies
Agenda

- Storage Solution Value – performance is the key!
- Performance Benchmarking
  - Simple vs. Comprehensive benchmarks
- Benchmarking New, complex storage devices and systems
- Storage Performance Council (SPC) Overview
- SPC benchmarks
  - High level description
  - Applications
Benchmark definition

A standardized test that is used as a basis for evaluation or comparison of computer system or component performance.

This presentation will focus on benchmarking performance factors that help define the value of a storage product from the customers perspective.
Performance is the key!

STORAGE SOLUTION VALUE
Product performance is much more than IOPS and Bandwidth

- **Availability**
  - HA strategy, MTBF, maintenance and scale out strategy

- **Data Path Performance**
  - IOPs, Bandwidth, Latency

- **Cost Performance**
  - CAPex - $/capacity, $/data path performance
  - Opex - $/hour of operation, $/data center floor tile

- **Energy Performance (efficiency)**
  - Watt/capacity, Watt/IOP

- **Form Factor Performance (density)**
  - Rack U/capacity, Rack U/data path performance

- **Scale up and out performance**
  - Max/Min capacity, ease of scale up, ease of scale out

In the end – only *customer visible* performance matters!
Product Attributes that can be tested

- **Availability**
  - HA strategy, MTBF, maintenance and scale out strategy

- **Data Path** Performance
  - IOPs, Bandwidth, Latency, Fairness

- **Cost** Performance
  - CAPex - $/capacity, $/data path performance, $
  - Opex -

- **Energy** Performance (efficiency)
  - Watt/capacity, Watt/IOP

- **Mechanical (Form Factor) Performance**
  - Rack U/capacity, Rack U/data path performance

- **Scale up and out performance**
  - Max/Min capacity, ease of scale up, ease of scale out

**Only customer visible performance matters!**
Performance data sources

- **Vendor specifications**
  - Good for the basics, minimum and maximum numbers
  - Form factor, scale up and out, HA strategy, etc.

- **Marketing material related to performance**
  - Usually simple benchmarks, focused on one or two metrics that highlight product differentiators
  - Good for absolute max performance numbers
  - May not help establish product value for a given application

- **Industry standard benchmarks**
  - The only source for repeatable, verifiable performance data.
  - The only way to do apples to apples comparisons across multiple vendors
Storage solution complexity

- Modern storage solutions are very complex
  - Multiple levels of cache
  - Several tiers of storage
  - Complex data movement algorithms
  - Many background tasks (maintenance, data motion)
  - Several types of connectivity
  - Compression, encryption, dedupe

- Individual storage devices are also complex
  - SSDs with complex wear leveling schemes
  - Hybrid SSD / HDDs
  - SMR HDDs

Simple benchmarks often bypass much of the complexity
Comprehensive “Real World” vs. simple benchmarks

- One option is a benchmark developed from a customer’s application workload
  - In-house benchmarks are expensive to develop and maintain, may be limited in scope and may not scale
  - Generally not practical to test multiple solutions
  - Difficult to compare products over longer periods of time since applications and data sets change

- The most useful benchmarks are well documented, reproducible and can be directly related to application workloads
  - Rich, complex workloads derived from traces
  - The full test configuration must be specified
  - The results must be reproducible outside the lab

- Simple, marketing benchmarks make great headlines but . . .
  - Are designed to sell products
  - May be “lab specials” (a configuration that can not be purchased)
  - Are not documented in enough detail to understand the test

Ask –
What is really being measured?
How can I relate this to my application?
Simple benchmark characteristics

- Often designed to achieve absolute maximum performance for a specific parameter
  - Executed in lab conditions by design engineers
  - Workload is optimized to achieve the desired result
  - Test configuration is optimized (may use unreleased and unsupported components)
  - All background tasks are turned off
  - Details of test configuration are often not disclosed

- Examples
  - Maximum IOPs (input / output operations per second)
  - Maximum bandwidth
  - Minimum latency

Simple benchmarks give little indication of what performance a customer may actually achieve in a production environment
Commonly used Simple Benchmarks

Anvil’s Storage Utilities
AS-SSD Benchmark
ATTO Disk Benchmark
Crystal Disk Mark
PCMark Vantage/7
IOMeter

Most useful to development engineers
SSD complexity example
R/W mix

• 100% reads are important for CD-ROM drives, not SSDs
• Most OSes are constantly writing in the background making 100% read tests irrelevant

Tests usually look at 100% reads or writes, but ignore your typical operating range

With only 5% writes, SSDs lose 50% to 80% IOP performance

Source – Flash Memory Summit 2013
Don’t let your favorite benchmarks lie to you
– Kent Smith - LSI
SSD complexity example - preconditioning

- Secure erase SSD for Fresh-Out-of-Box (FOB)
- After 16 minutes drive wrote 256GB (one full capacity write)
- Garbage Collection starts
- After ~62 minutes it wrote 2x capacity
- After ~3 hours it wrote 3x capacity, and finally hit steady state
- Now you can run drive tests to represent reality

SSDs must be filled to capacity before realistic performance measurement is possible

Source – Flash Memory Summit 2013
Don’t let your favorite benchmarks lie to you – Kent Smith - LSI
Benchmarking the new storage technologies

- New storage devices very sensitive to workload, test duration, unused capacity, I/O load and other factors

- Storage solution architecture is much more complex with many more SW optimizations running in parallel with the I/O load

Simple benchmarks can not be trusted to characterize the performance of complex devices and systems
Complex workload example

- Small block, random access
- Response time sensitive
- High locality
  - Bulk of I/O traffic goes to a small percentage of storage locations
  - Numerous hot spots
Complex workload example

- Small block, random access
- Response time sensitive
- High locality
  - Bulk of I/O traffic goes to a small percentage of storage locations
  - Numerous hot spots
- Hot spot characteristics
  - Some semi-permanent
  - Some transient
Covers the major measurable product performance characteristics

- Uses a workload derived from production application traces
  - Rich, complex, evolving over time
  - Hot spots, uneven load distribution

- Comprehensive reporting – covers all aspects of performance
  - Configuration, cost, energy consumption all disclosed

- Test configuration made up of production SW and HW components
  - Priced components must be available within three months of the SPC submission date

- Credible and repeatable
  - Audited by 3rd party and peer reviewed

Storage Performance Council benchmarks meet all of these requirements
STORAGE PERFORMANCE COUNCIL OVERVIEW
The SPC is a non-profit corporation founded in 1998 to accomplish the following:

- Define, standardize and promote the first industry-standard storage performance benchmarks
- Disseminate objective, verifiable storage performance data to developers and end-users/customers of computer systems

www.storageperformance.org
SPC Objectives

- Provide an incentive for storage performance improvements in the computer systems industry
- Enable end-users/customers to accurately compare storage products in a multi-vendor marketplace
- Establish a level “playing field” for storage vendors
- Publicize storage performance results
- Ensure accuracy and authenticity of those results
SPC benchmarks – the standard for the storage industry

- Inspired by the TPC and developed by a consortium of leading storage solution vendors
  - Established in 1998
- Uses workloads derived from real world applications
- Most major suppliers and many startups publish SPC benchmark results today
  - 232 results published as of Dec 2013
- Comprehensive
  - Complete configuration disclosure including cost
  - Data path performance, data integrity level, data persistence and energy consumption (optional) is reported
  - Both storage systems and components are covered by the benchmarks
- Compliance and credibility
  - Results are required to complete an audit and a 60 day peer review
SPC Membership

EMC Corporation
SPC Membership
SPC Membership consolidation

EMC Corporation  \( \leftrightarrow \) XtremIO

Lenovo \( \leftrightarrow \) compellent

IBM \( \leftrightarrow \) Texas Memory Systems, Inc.

Oracle \( \leftrightarrow \) Sun Microsystems

Violin Memory \( \leftrightarrow \) Gridiron

Avago Technologies \( \leftrightarrow \) LSI

Seagate \( \leftrightarrow \) Xyratex
Overview of performance parameters reported by SPC benchmarks

- **Availability related parameters**
  - The data persistence requirement confirms data is not lost or altered when the storage system is powered down
  - Data protection level is reported
    - Level 1 – a single storage device failure, Level 2 – the failure of any component in the configuration

- **Data Path Performance**
  - IOPs, Latency, throughput
  - Complex, realistic workloads
  - Extended run times (SPC-1 and SPC-1C)
  - Reported at several performance loading points

- **Cost**
  - All details of tested configuration are reported including cost

- **Capacity**
  - Detailed disclosure of storage capacity and how that capacity was utilized during the test

- **Energy (optional)**
  - Power consumption level is reported at several performance levels including idle

- **Other metrics can be derived from those that are reported**
  - Examples: $/IOP, Watts/IOP
SPC benchmark applications

- **Customer**
  - Compare solutions from several vendors
    - Max performance, typical performance, $/IOP, Capex, Opex, $/TB, etc.
  - Data center planning
    - Energy consumption reported at several IO load levels enable accurate power / cooling modeling for data center storage components

- **Analysts**
  - Benchmark results provide a clear view of product design tradeoffs
  - Best way to quickly cut through the marketing “hype”

- **Suppliers**
  - Marketing – product positioning and new product planning
  - Development – a tool that can be used by FW, HW and QA personnel
  - Management – a tool to track product development progress
    - Comprehensive and focused on customer value
SPC Benchmarks

- SPC Benchmark 1™ (SPC-1™)
- SPC Benchmark 2™ (SPC-2™)

SPC-1 and SPC-2 are the two “core” benchmarks of the SPC.

From those “core” benchmarks:
  - Component-level benchmarks
  - Energy extensions to measure power consumption
SPC Benchmark 1 (SPC-1)

- SPC-1 consists of a single workload that demonstrates storage performance for business critical applications
- A rich, complex workload
  - Mostly random IOPs
  - Includes hotspots
- Runtime ~ 8 hours sustained, 12 hours total run time
  - ASUs (Application Storage Unit) are pre-filled with random, uncompressible data before the benchmark is executed
  - Execution typically starts after a warm up period
- Similar applications
  - OLTP, Database operations, Mail Servers
SPC Benchmark 2 (SPC-2)

- SPC-2 consists of 3 distinct workloads that demonstrate storage performance of applications characterized by large scale sequential data movement

- Workloads
  - Large File Processing
    - Scientific computing, large scale financial processing, etc.
  - Large Database Queries
    - Relational data base scans, joins typical of data mining and business intelligence applications
  - Video on Demand
    - Multiple, large sequential file transfers typical of video on demand applications
SPC Component Benchmarks

- SPC-1C and SPC-2C provide performance measurement and comparison for storage components such as:
  - Storage devices (*HDDs and SSDs*)
  - HBAs/controllers
  - Small storage subsystems (*single enclosure*)
  - Processors used in the above components
  - Storage software such as Logical Volume Managers
SPC Component Benchmarks

- **SPC Benchmark 1C™ (SPC-1C™)**
  - SPC-1C is based on the SPC-1 benchmark specification and will utilize the single SPC-1 workload.

- **SPC Benchmark 2C™ (SPC-2C™)**
  - SPC-2C is based on the SPC-2 benchmark specification and will utilize the three SPC-2 workloads.
SPC Energy Extensions

- SPC Benchmark 1/Energy™ (SPC-1/E™)
- SPC Benchmark 2/Energy™ (SPC-2/E™)
- SPC Benchmark 1C/Energy™ (SPC-1C/E™)
- SPC Benchmark 2C/Energy™ (SPC-2C/E™)

Each SPC benchmark includes an optional energy extension, which includes energy use measurement and reporting.
Benchmark Disclosures

- Two required documents are submitted to the SPC for each SPC result –
  - Executive Summary (example – 11 pages)
  - Full Disclosure report which includes the Executive Summary (example – 88 pages)
  - Published at www.storageperformance.org

- Executive Summary content – (SPC-1example)
  - Sponsoring company and key dates
  - Summary of Results
  - Storage Capacities, Relationships and Utilization
  - Response Time – Throughput Curve
    - 10% to 100% load
  - Priced Storage Configuration
    - Including components and support costs
    - Includes a configuration diagram
Summary of Results

<table>
<thead>
<tr>
<th>Tested Storage Product (TSP) Name: Kaminario K2 (K2F00000700)</th>
<th>SPC-1 Reported Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>Reported Result</td>
</tr>
<tr>
<td>SPC-1 IOPS&lt;sup&gt;TM&lt;/sup&gt;</td>
<td>1,239,898.00</td>
</tr>
<tr>
<td>SPC-1 Price-Performance&lt;sup&gt;TM&lt;/sup&gt;</td>
<td>$0.80/SPC-1 IOPS&lt;sup&gt;TM&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total ASU Capacity</td>
<td>60,129.542 GB</td>
</tr>
<tr>
<td>Data Protection Level</td>
<td>Protected 2 (K-Raid)</td>
</tr>
<tr>
<td>Total Price</td>
<td>$997,348.00</td>
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<tr>
<td>Currency Used</td>
<td>U.S. Dollars</td>
</tr>
<tr>
<td>Target Country for availability, sales and support</td>
<td>USA</td>
</tr>
</tbody>
</table>
SPC-1 Performance

Response Time / Throughput Curve

100%, 95%, 90%, 80%, 50% and 10% of the maximum specified BSU level

8,012 BSUs, 400,600 SPC-1 IOPS maximum
### SPC-1/E – Various Performance Loads

<table>
<thead>
<tr>
<th>Execution Component</th>
<th>Load Level</th>
<th>SPC-1 IOPS™</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOPS (100%)</td>
<td>100%</td>
<td>195,021.70</td>
<td>382.82</td>
</tr>
<tr>
<td>Ramp95 (95%)</td>
<td>95%</td>
<td>185,250.57</td>
<td>379.58</td>
</tr>
<tr>
<td>Ramp90 (90%)</td>
<td>90%</td>
<td>175,489.82</td>
<td>379.00</td>
</tr>
<tr>
<td>Ramp80 (80%)</td>
<td>80%</td>
<td>156,026.23</td>
<td>370.51</td>
</tr>
<tr>
<td>Ramp50 (50%)</td>
<td>50%</td>
<td>97,504.04</td>
<td>351.56</td>
</tr>
<tr>
<td>Ramp10 (10%)</td>
<td>10%</td>
<td>19,512.06</td>
<td>216.98</td>
</tr>
</tbody>
</table>

**Power/Performance Profile - Ramp**

- **100%**: 382.82 W, 195,021.70 IOPS
- **95%**: 379.58 W, 185,250.57 IOPS
- **90%**: 379.00 W, 175,489.82 IOPS
- **80%**: 370.51 W, 156,026.23 IOPS
- **50%**: 351.56 W, 97,504.04 IOPS
- **10%**: 326.98 W, 19,512.06 IOPS
### SPC-1/E – Idle Test

<table>
<thead>
<tr>
<th>Execution Component</th>
<th>Load Level</th>
<th>SPC-1 IOPS™</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle – Conditioning (Condition)</td>
<td>100%</td>
<td>194,993.76</td>
<td>382.89</td>
</tr>
<tr>
<td>Idle (Idle-L)</td>
<td>0%</td>
<td>0.00</td>
<td>320.44</td>
</tr>
<tr>
<td>Idle - Recovery (Recovery)</td>
<td>10%</td>
<td>19,489.22</td>
<td>326.62</td>
</tr>
</tbody>
</table>

#### Power/Performance Profile - Idle

- **Condition**: 382.89 W; 194,993.76 IOPS
- **Idle-L**: 320.44 W
- **Recovery**: 326.62 W; 19,489.22 IOPS

![Power/Performance Profile - Idle](image-url)
An SPC auditor must certify that a benchmark result is eligible for submission before any information is published.

SPC auditors are independent and not associated with any SPC member companies.

On-site audits
- An SPC auditor reviews the test configuration and procedures on the test sponsor’s site.

Remote audits can be conducted under certain limited circumstances.

All benchmark results are subject to a 60 day peer review process before they are “accepted”.
Summary

- Customer value is largely determined by product performance
  - Product performance is more than just IOPS and bandwidth

- Modern storage devices and systems are very complex making it more difficult to properly benchmark product performance

- Simple benchmarks are good engineering tools but can’t be trusted to evaluate overall product performance

- Comprehensive, industry standard benchmarks level the playing field and allow apples to apples product comparisons

- The Storage Performance Council benchmarks are still the gold standard for evaluating storage component and solution performance.
Thank you!

This presentation includes a high level introduction to the SPC benchmarks

Please visit www.storageperformance.org

For benchmark results, benchmark specifications and membership information