Product/Family, Best Foot Forward (BFF), Test Points and Qualification Ranges

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Herb Tanzer - HP
Agenda

- Product/Family/Best Foot Forward (BFF) Descriptions
- BFF Methodology and Examples
- Emerald™ and ENERGY STAR® Test Point and Qualification Range Definitions
Presenters

Jim Espy - EMC
▷ Current Title: Senior Consulting Engineer
▷ Experience: 30+ years in storage and related industries

Herb Tanzer – HP
▷ Current Title: Storage Hardware Architect
▷ Experience: 30+ years in storage and related industries
Product/Family Problem Statement

Wide Spectrum of Storage-Oriented Products
- Created a taxonomy to narrow scope
- Categories: On-Line, Near-Line, etc.
- Classifications: Further granularity of each Category

Still too Broad in Scope
- Vendors may have multiple Category/Classification products
- Each product may have many configuration variables

Requirement/Challenge: Select Appropriate Test Configs
- Comprehensive and usable results for customer
- Minimized, lower cost, but effective testing methods for vendor
Concept of Product and Family

- **Product:**
  - Represents a fundamental performance capability space that separates it from any other potentially related products.

- **Product Family:**
  - Represents the full range space of configuration variables and options for a particular product.

- **Term Usage:**
  - Terms *family* and *range* are used interchangeably and may include such aspects as number and type of storage devices (spinning or solid state drive), cache size, availability levels, etc.
**Approach**

- **Vendor Aligns Product(s) with SNIA Taxonomy Category**
  - Hopefully straightforward – Taxonomy will adapt over time

- **Vendor Aligns Product(s) with Category Classification**
  - Will be some boundary gray areas - E.g. OL-3 or OL-4?

- **Vendor Further Defines Product/Family Configurations**
  - The really hard part…

- **Conceptual Representation**
  - Next slide depicts a possible product/family (range) differentiation
  - Believed applicable to most storage system architectures
Simplified Product/Family Representation

Range (E.g. Capacity)

Expansion

Base (Entry)

Performance

Product A
Product B
Product C

Product Range Variable Space

Product Performance Capability Space
Product/Family Discussion

- **Products Could be of Various Architectural Types**
  - Monolithic – Little or no scaling but may still have family aspects
  - Scale-up – E.g. base controller + storage expansion
  - Scale-out – E.g. base compute/storage + compute/storage expansion
  - Others TBD

- **Product Performance Typically Scales With Expansion**
  - Varying degrees
    - Scale-up performance typically rolls off at varying degrees before max config
    - Scale-out performance can be linear with increasing configurations
  - Inter-product performance overlap driven by vendor’s market positioning
Family (Range) Discussion

Range Variables
- Example on previous product/family depiction focuses on capacity
- Could involve other variables

Range Variable Types
- Particular Items of highest potential energy consumption impact:
  - Controller or related compute element – Typically defines performance aspect
  - Cache – Also perf oriented - Not considered part of the user-addressable space
  - Number and type of persistent storage devices – Defines user-addressable space
  - RAS items – As necessary for reliability, availability, serviceability requirements
  - Capacity optimization – Functionality (typically software) that more effectively utilizes physical storage space, e.g. thin provisioning, compression, de-duplication
- Many other examples
  - Power supplies, cooling, I/O, etc.
Approach to Range Variable Reduction

Range Variable Reduction is Difficult
- Even with the 5 listed items, still too many test cases
  - Significant set-up and execution times
  - Complex results sets
- Max system size testing is expensive and cumbersome to manage
- Need a simpler alternative…

“Best Foot Forward” (aka Sweet Spot) - BFF
- Find proxy family configuration(s)
  - Intended to be reasonably representative of the all range variables
- Find test point(s) where Measurement Spec active metrics are best
  - The “sweet spot”
- Suitable for any architecture
  - E.g. scale-up, scale-out, hybrid, …
Best Foot Forward Approach

- **BFF Looks Holistically at Storage System Product/Family**
  - Allows vendor to select and test one product/family configuration
    - Or more if desired
  - At operating points near the Measurement Spec metric peak values
    - I.e. the “sweet spot”
  - Results reasonably representative of the entire family
    - Easier and less expensive for the vendor
    - Simple and understandable results for the potential customer

- **Scale Up Example on Following Slide**
  - Notion that Measurement Spec active metrics have peak values
  - Peaks typically located at points below maximum configurations
Best Foot Forward Approach
Scale-Up System

Approximate region of “best” or peak Performance/W

Base Performance/W

Varying roll-off behaviors by product.
Best Foot Forward Approach

- Previous Slide is a Rough Approximation
  - Capacity increases are actually more stepwise
  - Degree of performance roll-off can vary by product
    - Dashed lines attempt to show one (of possibly many) changes due to different storage technology tiers, e.g. scaling capacity w/large SATA drives
  - Storage device enclosures shelves may impact
    - Efficiencies of partial vs fully populated shelves
  - Regardless, example depicts a smaller test configuration

- Scale Out Example on Following Slide
  - What if there no clearly discernible peak for a reasonable test config?
Best Foot Forward Approach
Scale-Out System

- Theoretical homogeneous scale-out
- Theoretical heterogeneous scale-out
- Selected region of “best” or peak
  Performance/W

Capacity (Cache, End Storage)

“Typical” Performance

Base

Power

Base Performance/W
Best Foot Forward Approach

- Again a Rough Approximation
  - Capacity increases are actually more stepwise
  - Dashed lines attempt to show one (of possibly many) changes due homogeneous vs heterogeneous scale-out configurations
  - Can still select a smaller test configuration
Summary and Next Steps

**Given Known Taxonomy Category and Classification**
- Vendor determines one or more family representative configurations
- Vendor locates Measurement Spec active metric peak points
- Tests are performed on this reduced configuration (set)
  - Note: For smaller systems, the BFF may in fact be the maximum configuration

**Where is the Performance/W Peak?**
- Depends on numerical increase of performance numerator vs power denominator with capacity
- If numerator initially increases more than denominator, a clear peak
- Else it becomes harder – Just pick a point before it rolls off?
Next: BFF Methodology and Examples
The benefit of Best Foot Forward (BFF) is to reduce the full range of variables of a product family to just a few test configurations. This reduced test set can be considered representative of the entire product family.

The BFF consists of the configurations that will produce a set of peak power efficiency metrics of a product family for the different test phases:
- Random [IO/s/Watt]
- Sequential [MiB/s/Watt]
- Idle Capacity [GiB/Watt]
A general approach for Emerald data submission

- Start by aligning your product family within a taxonomy definition
- Consider a baseline run to establish the test process “get a feel”
  - Start w/ available configuration; no particular “tuning” in affect
  - Identify any issues with conditioning, stability, response times, etc. (per the run rules), post-processing, reporting, etc.
- Consider all possible (and valid) product SKU’s to identify configurations that will give the peak power efficiency metrics
- With the help of Estimator tools, identify the “best-foot-forward” or “sweet-spot” relative to each specific test profile
- Set-up, test, and measure the peak metric values for your 1st BFF
  - Run through the complete sequence of test phases
  - Test validate and data correlate
- For each additional BFF of interest, re-configure and re-test
Candidate SUT: A shipping Online-3 SAN

- Two controller performance points, with variable cache and front-end interfaces
- The lower product class can support 120xLFF or 250xSFF and the higher product class can support 240xLFF or 450xSFF (6Gb SAS)

- SFF
  - 146GB, 15K
  - 300GB, 10K
  - 450GB, 10K
  - 600GB, 10K
  - 500GB, 7.2K midline
  - 200GB SSD*
  - 400GB SSD*

- LFF
  - 300GB, 15K
  - 450GB, 15K
  - 600GB, 15K
  - 2TB, 7.2K midline
Test Phase IO Profiles for Online & Near Online

- The complete test is run in an un-interrupted sequence, and consists of Pre-fill, Conditioning, the Active tests, and Ready Idle.

- Each Active IO test phase IO profile shall last a minimum of 40 minutes, comprised of a minimum of 10 minutes to establish stability followed by 30 minutes as the measurement interval.

<table>
<thead>
<tr>
<th>IO Profile</th>
<th>IO Size (KIB)</th>
<th>Read/Write Percentage</th>
<th>IO Intensity</th>
<th>Transfer Alignment (KIB)</th>
<th>Access Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Band Workload (I=HB)</td>
<td>See Table 11</td>
<td>See Table 11</td>
<td>100</td>
<td>See Table 11</td>
<td>See Table 11</td>
</tr>
<tr>
<td>Random Write (I=RW)</td>
<td>8</td>
<td>0/100</td>
<td>100</td>
<td>8</td>
<td>Random</td>
</tr>
<tr>
<td>Random Read (I=RR)</td>
<td>8</td>
<td>100/0</td>
<td>100</td>
<td>8</td>
<td>Random</td>
</tr>
<tr>
<td>Sequential Write (I=SW)</td>
<td>256</td>
<td>0/100</td>
<td>100</td>
<td>256</td>
<td>Sequential</td>
</tr>
<tr>
<td>Sequential Read (I=SR)</td>
<td>256</td>
<td>100/0</td>
<td>100</td>
<td>256</td>
<td>Sequential</td>
</tr>
</tbody>
</table>

- A 2-hour ready idle test follows the Active tests.
Combined Vdbench /Power Analyzer Plot

Peak Transactional Efficiency Metric ~ 17 IO/s/W

Peak Throughput Efficiency Metric ~ 1.2 MB/s/W

Note: Power varies between 451W at idle to 513W at RR (13.4%)
Finding the Best Foot Forward

Since there are 6 different Emerald test profiles for Online we can expect up to 6 different BFF configurations
- 1 X Hotband (IOP/S/Watt)
- 2 x Random [IOP/S/Watt]
- 2 x Sequential [MiB/S/Watt]
- 1 x Ready-Idle [raw capacity, GiB/Watt]

Recommend using Estimator tools that combine power and performance to predict the peak metrics
- The alternative is educated derivations and potentially a lot of testing that is very labor and resource intensive
- As long as the simulated results are reasonably accurate, the physical number of test points taken can be reduced
# Predicted peak metrics for an Online-3 test candidate

<table>
<thead>
<tr>
<th>Exercise #</th>
<th>Prediction basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mixed Workload, Random 70/30 R/W</td>
</tr>
<tr>
<td>2</td>
<td>Random Read (100/0 R/W) &amp; Random Write (0/100 R/W)</td>
</tr>
<tr>
<td>3</td>
<td>Sequential Read (100/0 R/W) &amp; Sequential Write (0/100 R/W)</td>
</tr>
<tr>
<td>4</td>
<td>Ready Idle</td>
</tr>
</tbody>
</table>

Note: For these modeling exercises, drive count is incremented by full drive shelf.
Exercise 1: Mixed Workload
8K Random 70/30 R/W

SFF 15K rpm, RAID 5

- Peak metric = 12.7 IOP/S/Watt at 125 drives
- Changing the read/write mix changed the peak metric but not the drive count
  60/40 r/w = 11.5 IOP/S/W; 80/20 r/w = 14.9 IOP/S/W
Exercise 2: 8K Random Read, Write

SFF 15K rpm, RAID 5

Random Read

IOPS/Watt

Peak Metric: 23.5 IOP/S/Watt and 125 drives

Random Write

IOPS/Watt

Peak Metric: 7.3 IOP/S/Watt and 75 drives
Exercise 3: 128K Sequential Read, Write

SFF 15K rpm, RAID 5

**Sequential Read**

- No. of Disk Drives vs. MBS/Read
- No. of Disk Drives vs. Watts

**Sequential Write**

- No. of Disk Drives vs. MBS/Write
- No. of Disk Drives vs. Watts

Peak Metric:
- 1.63 MB/S/Watt and 25 drives
- 1.0 MB/S/Watt and 50 drives
Exercise 4: Ready-Idle

LFF 2TB 7.2K rpm and SFF 500GB 7.2K rpm drives at Ready-Idle

Peak Metrics:
LFF: 138.8 GB/W and 240 drives
SFF: 76.6 GB/W and 450 drives
General Observations for the Candidate SUT

- **Active cases** - the Performance* reaches a highest rate relatively early (i.e., smaller drive count) before rolling off and leveling. The peak [Performance/Power] metric seems to coincide with the rate inflection
  - All peak predictions for Random are reached with the same drive type (15K, SFF) and close in drive count (125 or 75)
  - All peak predictions for Sequential reached with the same drive type (15K, SFF) and close in drive count (50 or 25)

- **Ready-idle case** - the peak metric levels but continues to slowly rise with drive count (as the controller electronics power is amortized over increasing numbers of drives)

*Note: very dependent on specific Controller performance and bandwidth behavior*
Next: Emerald™ and ENERGY STAR® Test Point and Qualification Range Definitions
Emerald Test Point Definition

- BFF Performance/Watt point
  - For all vendor-selected product/storage device configurations

- Could Test at Other Capacity Points but not Required
ENERGY STAR Test Point Definitions

- **BFF Performance/Watt point**
  - For all vendor-selected product/storage device configurations

- **Two Additional Performance/Watt points**
  - For particular product configuration but *only for most commonly sold and shipped storage device type*
  - Either:
    1) -40% and +15% of the BFF storage device count
    - or-
    2) Storage device count points where Perf/W value is 15% < the BFF point

Whichever provides the wider Performance/Watt curve coverage
Test Point Definitions
Scale-Up System Example

- **BFF Perf/W**
- **BFF Perf/W − 15%**
- **Could be flipped**
- **Could be flipped**

### Device Count

<table>
<thead>
<tr>
<th>Device Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DC_{BFF}$</td>
<td>Device count at BFF Perf/W</td>
</tr>
<tr>
<td>$DC_{1a}$</td>
<td>$DC_{BFF} - 40%$</td>
</tr>
<tr>
<td>$DC_{1b}$</td>
<td>$DC_{BFF} + 15%$</td>
</tr>
<tr>
<td>$DC_{2a}$</td>
<td>Device count at BFF Perf/W − 15% (left); equivalent $DC_{BFF} - X%$</td>
</tr>
<tr>
<td>$DC_{2b}$</td>
<td>Device count at BFF Perf/W − 15% (right); equivalent $DC_{BFF} + Y%$</td>
</tr>
</tbody>
</table>
Collect SUT Data – Then What?

**For Emerald**
- Complete TDR(s)
  - Product configuration/storage device type(s) and BFF data test point(s)
  - Product configuration and storage device types/combinations you choose

**For ENERGY STAR**
- Submit Test Data
  - Product configuration/storage device type(s) and all required data test point(s)
  - Product configuration and storage device types/combinations you choose

*But What Defines an ENERGY STAR Qualified Product?*
A.k.a. “Fixed” Qualified Range

Qualification Range Option 1

If:
  > Test points utilize -40% and +15% of the BFF storage device count

Then:
  > Qualified range extends from -20% to +5% of the BFF storage device count

Further If:
  > Perf/W values at -40% and (or) +15% device counts are > BFF Perf/W – 15% level

Then
  > Qualified range widens to -40% and (or) +15% of the BFF storage device count

Qualification Range Option 2

If:
  > Test points utilize storage device count points where Perf/W values = BFF Perf/W value - 15%; equivalent of -X% and +Y% of the BFF storage device count

Then:
  > Qualified range extends from -X% to +Y% of the BFF storage device count

Goal is to select the option providing the widest qualified range.

Can also round up/down to the nearest drawer.

A.k.a. “Flexible” Qualified Range
ENERGY STAR Qualification Range Option 1 Example (corrected)

<table>
<thead>
<tr>
<th>Device Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC_BFF</td>
<td>Device count at BFF Perf/W</td>
</tr>
<tr>
<td>DC_1a</td>
<td>DC_BFF - 40%</td>
</tr>
<tr>
<td>DC_1b</td>
<td>DC_BFF + 15%</td>
</tr>
<tr>
<td>QR_1a</td>
<td>DC_BFF - 20%</td>
</tr>
<tr>
<td>QR_1b</td>
<td>DC_BFF + 5%</td>
</tr>
</tbody>
</table>

Corrected curve shape

Qualified Range

BFF Test Point

BFF Perf/W

Performance/Watt

Capacity (Device Count)
ENERGY STAR Qualification Range Option 1 Example Extended (Widened)

Since the Perf/W values at -40% and (or) +15% device counts are greater than the BFF Perf/W – 15% level, the qualified range can be widened.

<table>
<thead>
<tr>
<th>Device Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DC_{BFF}$</td>
<td>Device count at BFF Perf/W</td>
</tr>
<tr>
<td>$DC_{1a}$</td>
<td>$DC_{BFF} - 40%$</td>
</tr>
<tr>
<td>$DC_{1b}$</td>
<td>$DC_{BFF} + 15%$</td>
</tr>
<tr>
<td>$QR_{1a}$</td>
<td>$DC_{1a}$</td>
</tr>
<tr>
<td>$QR_{1b}$</td>
<td>$DC_{1b}$</td>
</tr>
</tbody>
</table>
ENERGY STAR Qualification Range
Option 2 Example: X=60%; Y=20%

Note that this method rewards a flatter Perf/W curve; i.e. higher efficiency over a wider device count range.

<table>
<thead>
<tr>
<th>Device Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC_{BFF}</td>
<td>Device count at BFF Perf/W</td>
</tr>
<tr>
<td>DC_{2a}</td>
<td>Device count at BFF Perf/W – 15% (left); equivalent DC_{BFF} – X%</td>
</tr>
<tr>
<td>DC_{2b}</td>
<td>Device count at BFF Perf/W – 15% (right); equivalent DC_{BFF} + Y%</td>
</tr>
<tr>
<td>QR_{2a}</td>
<td>DC_{2a}</td>
</tr>
<tr>
<td>QR_{2b}</td>
<td>DC_{2b}</td>
</tr>
</tbody>
</table>
ENERGY STAR – further extensions to the Qualification Range

- Test points exist for up to five Active + one Idle conditions
- Rounding to full drawers
- Combinations of single device type optimal configurations, based on percentage allocation of devices
- Storage device replacement (if similar or better)
- Multiple device type optimal configurations (must have auto-tiering technology)
  - Auto-tiering BFF or optimal configuration is not yet fully understood, but it is suggested that initial submissions are representative of actual selling systems.
  - Maintain ratios of device types for \(-X\% / +Y\%\) test points
ENERGY STAR Qualification Range

- Whichever Qualification Range Method is Determined
  - Any extension to the qualified range based on testing of the most commonly sold and shipped storage device type may be applied to additional storage devices within the same product and workload type, without the need to physically retest the outer points
  - BFF point still needs to be tested for each additional storage device
Example Test Points
ENERGY STAR (Online 4)

Sequential workload optimized
Derived optimal based on 50/50 weighing
Test points for optimal: -40%, and +15% drive count
Qualified range: -15% to +5% of optimal, with rounding
### Operational Power

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Average Watts</th>
<th>Raw Capacity</th>
<th>Standard Idle Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle power test</td>
<td>560.7 W</td>
<td>18.9 TB</td>
<td>GB per Watt</td>
</tr>
<tr>
<td>EP&lt;sub&gt;RI&lt;/sub&gt;</td>
<td></td>
<td>33.7 GB/W</td>
<td></td>
</tr>
</tbody>
</table>

### Active power tests

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Run Length (minutes)</th>
<th>Average Latency (RTA&lt;sub&gt;RR&lt;/sub&gt;(1800) &lt;= 20 ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP&lt;sub&gt;RR&lt;/sub&gt;</td>
<td>8.45</td>
<td>15.53 ms</td>
</tr>
<tr>
<td>Small random reads</td>
<td>I/Os per second per Watt</td>
<td></td>
</tr>
<tr>
<td>EP&lt;sub&gt;RW&lt;/sub&gt;</td>
<td>3.54</td>
<td>18.59 ms</td>
</tr>
<tr>
<td>Small random writes</td>
<td>I/Os per second per Watt</td>
<td></td>
</tr>
<tr>
<td>EP&lt;sub&gt;SR&lt;/sub&gt;</td>
<td>2.7</td>
<td>8.17</td>
</tr>
<tr>
<td>Large sequential reads</td>
<td>MiB per second per Watt</td>
<td></td>
</tr>
<tr>
<td>EP&lt;sub&gt;SW&lt;/sub&gt;</td>
<td>1.18</td>
<td>5.42</td>
</tr>
<tr>
<td>Large sequential writes</td>
<td>MiB per second per Watt</td>
<td></td>
</tr>
<tr>
<td>EP&lt;sub&gt;HB&lt;/sub&gt;</td>
<td>14.34</td>
<td>18.55 ms</td>
</tr>
<tr>
<td>Hot band workload</td>
<td>I/Os per second per Watt</td>
<td></td>
</tr>
<tr>
<td>Random + sequential workload w/ hot spots</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** Power-related numbers are required to be reported to three significant digits.

**Note:** Publishing latency data is optional.

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**The SNIA Emerald Test Data Report**

Disclosure for storage systems and products

Version 2.0.2-03-Exp2

**Capacity Optimizations**

- Deduplication
- Compression
- Thin provisioning
- Parity RAID
- Read-only delta snapshots
- Writeable delta snapshots

On during test? | Available in SUT?
--- | ---
no | yes
no | no
no | yes
yes | yes
yes | yes
no | yes

This TDR is for a 42 drive count configuration, which is the derived optimum drive count test point (50/50 weighing) required by the EPA for the separate SeqR and SeqW workloads.
Thank You

Questions?

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- herb.tanzer@hp.com