z/VM Paging with SSD and Flash-Type Disk Devices

Version 2.6

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Agenda

- Choosing the right disk storage
- High Performance Paging Options
- The Need for Faster Paging
- Case Study
Choosing the Right Disk Storage
So Many Choices

ECKD
- Dedicated
- FullPack
- Minidisk

SCSI
- Dedicated
- EDEV

VDisk

No MDC
- MDC

No PAV
- Host PAV
- Guest PAV

Choices at Linux Level
Look at All Attributes – Not Just One

Choice

- RAS
- Business Continuity & Disaster Recovery
- Provisioning and Systems Management
- Management of Devices
- Price
- Performance
- Capacity
A “loose” z/VM ECKD to SCSI Comparison

**ECKD**
- 1TB disk supported
  - Full volume only beyond 65520 cyl
- Flashcopy & PPRC supported from host
- Exploits HyperPAV concurrent I/O on behalf of guests, or if guest exploits
- Supported by GDPS
- Less host CPU utilization per start
- Host backup to FICON Tape
- No midrange storage option available
- Supports solid state DASD options
- Fully supported by SSI
- No concurrent code load issues
- Eliminates WWPN Management, but consumes space for Count/Keys

**SCSI**
- 1 TB – 4K CP LUN supported
  - Guest LUN up to hardware max
- Flashcopy & PPRC supported only from hardware interfaces
- Exploits concurrent I/O for CP paging (except XIV), or if guest exploits
- No GDPS
- High host CPU utilization per start for CP managed volumes, very low utilization for guest passthru
- No host backup to SCSI tape, but guest can backup to SCSI tape
- Supports V7000 or other midrange storage through an SVC
- Supports solid state DASD options & IBM Flash Systems (z/VM 6.4)
- SSI PDR & Install not supported
- WWPN Management Issues

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A Few More Things to Think About

- Prior to z/VM 6.4, there was no HyperPAV support for z/VM system volumes (paging). So migrate to 6.4 or beyond for this support.

- Even if ECKD volumes could be infinitely large and infinitely fast, we would probably still want as many as there are logical processors for z/VM.

- FCP SCSI for z/VM Paging provides a level of parallelism but at a cost in processor time
  - Greater Bandwidth
  - Higher CPU costs
High Performance Paging Options
Flash vs. SSD and Terminology

- Purists will say “Flash” is not the equivalent of “SSD”
  - Solid State Disk – most often used to describe a device where the access is through an existing disk interface
  - Flash – access to it via direct interface to the memory

- Common Attributes:
  - Storage capacity
  - Write speed
  - Read speed
  - Active power
  - Standby power
  - Write endurance or wear-out
  - Type: NAND, NOR
Flash Express

- Flash Express Feature of zEC12 and zBC12 processors

- PCIe I/O Adapter with NAND Flash SSDs

- Accessed using Extended Asynchronous Data Mover Facility (EADMF)

- RAID 10 mirrored Pairs

- Protected with 128-bit AES encryption

- Maximum of 4 Cards provides 5.6 TB of usable storage

- Not supported by z/VM at this time. 😞
IBM FlashSystem

- IBM FlashSystem V840 - Based off technology from acquired Texas Memory System
  - Uses eMLC Flash

- FCP SCSI Only

- Prior to z/VM 6.4, to use as z/VM Paging volumes, must be behind an SAN Volume Controller (SVC)
  - Some models of FlashSystem include SVC
  - Restriction lifted with z/VM 6.4 GA November 11, 2016

- Various Features:
  - Easy Tier support
  - Compression
  - Data replication
DS8870

- Part of the IBM DS8000® Series

- Can be equipped with SSD drives

- HPFE (High Performance Flash Enclosure) – Newest Option

- ECKD or FCP SCSI

- Lots of features/capabilities
  - RAID 5,6,10
  - Easy Tier
  - GDPS
  - Encryption
  - Etc.

- Maximum configuration 3072 TB
Flash also Available for Other Options

- Storwize V7000
  - Internal flash drives available
  - External IBM FlashSystem Storage

- XIV
  - Flash optimized options
The Need
I/O Rates and Latency

- Two aspects of paging I/O
  - Overall capacity: IOPS or MB/Second
  - Performance or Latency: delay per page read

- Historically, top-end storage servers could not be saturated by z/VM Paging

- Changing History:
  - Larger amount of memory supported and page rates increasing
    - If z/VM 6.3 allows 4 times number of virtual machines, then 4 times the page rate when you add those virtual machines.
  - Elimination of scaling problems in z/VM that allow greater paging rates
  - Better determination of the actual disk paging bandwidth
    - z/VM 6.3 algorithms changed to better estimate and utilize disk paging bandwidth
Apache Workload in Scaling Overcommitted

- As workloads scale up, the paging I/O rates will as well.
- There is no PAV or HyperPAV for z/VM paging to help scenario

ETR = External Throughput; ITR = Internal Throughput; DASD ST = Paging DASD Service Time
Virtual to Real Memory Overcommitment

- One of the factors often forgotten is the performance (capacity and bandwidth) of the paging configuration.

- A 100 GB real memory system with 125 GB of active virtual memory basically means being able to constantly turn over 25 GB – Potentially more based on the amount of memory that is changing and resulting in page writes in addition to page reads.

- As virtual machines are delayed for paging, pages that are resident tend to be needed longer, creating more demand and potential spiral-effect.
Paging Best Practices

- All paging volumes should have the same attributes: Size, Performance, etc.

- Do not mix page space with other data types

- Do not mix FCP SCSI and ECKD paging volumes

- Be aware of any shared hardware in the path (channels, control units) and who/what is sharing them

- Follow planning guidelines for amount of space
Case Study
Customer Proof of Concept

- Customer moved paging volumes from multiple z/VM LPARs and CECs to a DS8870

- For this study, everything was placed in one Logical Control Unit (LCU)
  - This is not recommended but for part of the experiment
  - Limiting to one LCU restricted full use of DS8870 cache and processing power

- The area that came under question what happens when you IPL multiple z/VM systems and need to restart 100s and 100s of virtual machines?
Key Observations

- Performance of DS8870 is a significant improvement over spinning disk.

- No single number can really portray that performance.

- Factors that will be examined:
  - Peaks across different LPARs
  - Data per I/O
  - Read / Write Ratio

- Study will explore the data in the different dimensions above.

- Brief comparison to the non SSD storage servers.
### Summary of Systems from April 13th Data

<table>
<thead>
<tr>
<th>LPAR</th>
<th>z/VM</th>
<th>Page Vols</th>
<th>Memory Virt:Real</th>
<th>IPL Time</th>
<th>Peak Page Rate</th>
<th>Peak Page Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPAR1</td>
<td>6.3.0</td>
<td>43</td>
<td>2.36</td>
<td>15:11:14</td>
<td>73690</td>
<td>16:04:00</td>
</tr>
<tr>
<td>LPAR2</td>
<td>6.3.0</td>
<td>41</td>
<td>2.34</td>
<td>15:51:33</td>
<td>39865</td>
<td>17:10:00</td>
</tr>
<tr>
<td>LPAR3</td>
<td>6.3.0</td>
<td>29</td>
<td>1.76</td>
<td>15:11:30</td>
<td>39800</td>
<td>16:16:00</td>
</tr>
<tr>
<td>LPAR4</td>
<td>6.3.0</td>
<td>49</td>
<td>2.48</td>
<td>15:41:23</td>
<td>93229</td>
<td>16:38:00</td>
</tr>
<tr>
<td>LPAR5</td>
<td>6.3.0</td>
<td>27</td>
<td>2.36</td>
<td>15:11:34</td>
<td>170</td>
<td>21:01:00</td>
</tr>
<tr>
<td>LPAR6</td>
<td>6.3.0</td>
<td>10</td>
<td>0.87</td>
<td>15:11:10</td>
<td>30</td>
<td>15:26:00</td>
</tr>
</tbody>
</table>

- Peak Page Rate: 4KB Pages/Second, includes read and write
- IPL Time: Time at which z/VM system was IPLed, not necessarily when all virtual machines were brought online.
- LPAR5 and LPAR6 are boring, from a performance perspective.
I/O from LPAR5 and LPAR6 are insignificant.
LPAR4 Data spans much longer time, though the highest rates are caused by it.
First we'll focus on the different IPL spans.
There is a large spike when enough virtual machines are active that we start to overcommit memory.

For a period of time the system works hard to reach steady state.

The larger the overcommitment, the larger the spike.

Not all peaks occur at the same time.

And not all I/O is equal…
Stacking the I/O to get total going to DS8870 gives you a portrait that reflects the peaks of different I/Os.

- The peak of 4983 IOPS is at 16:46:00
Individual Paging Volumes have consistent usage and characteristics.

To keep sanity, future charts will look at z/VM System wide information.
All the z/VM systems showed similar trends.

Larger amounts of data are paged out with single host I/Os early in the initial paging after IPL.

Variation continues to occur, but is most significant 15 to 30 minutes after start of overcommitment.

Will look at another aspect on next chart.
The read to write ratio changes drastically through the period. In the early stages, data written is orders of magnitude more than data read.
Paging I/O Service time is often under 1 millisecond.
Though there are several spikes where it is higher.
But, remember how the amount of data per I/O and the read/write ratios changed.
Early numbers are anomalies from small denominators, prior to load starting.

Some spikes look scary, but remember scale. Is 1/100th of a millisecond.

Some of the spikes correlate with activity on other LPARs. Remember everything is in one LCU at this time.
Write cache, as expected is almost always 100% (or 0% when no I/O takes place).

Very limited benefit from additional write cache.
No reads prior to overcommitment
Initially, 100% read hit and then settles down.
Pct hit shown is of that LPAR’s I/Os, not all I/Os to DS8870
Potential benefit from additional cache.
Does the new DS8870 Make a Difference?

- Yes!

- How much is always hard to quantify without perfectly controlled environment.

- A few items from LPAR1 (Remember not apples to apples)
  - Shutdown processing is as “interesting” as IPL processing

<table>
<thead>
<tr>
<th>Metric</th>
<th>w/o DS8870</th>
<th>w/ DS8870</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mload (z/VM Measurement of Paging Subsystem Performance)</td>
<td>36.8</td>
<td>3.7</td>
<td>-90%</td>
</tr>
<tr>
<td>Average Queue Length of Paging Volumes</td>
<td>12.9</td>
<td>0.44</td>
<td>-97%</td>
</tr>
<tr>
<td>Average %PGW from State Sampling</td>
<td>6%</td>
<td>0%</td>
<td>-100%</td>
</tr>
<tr>
<td>Average Service Time on Paging Volumes (milliseconds)</td>
<td>17.4</td>
<td>0.21</td>
<td>-99%</td>
</tr>
</tbody>
</table>
Remember Other Spikes on LPAR4?

LPAR4 - Page I/O Rates - April 13th

- Each caused by a different set of guests becoming more active and a flurry of activity.
Selected Page Read size here as Guests (and applications) wait for page reads, not page writes.

Remember I/O characteristics vary.
Perfect Storms

- The z/VM systems are started at different offsets, but spent some time looking at what would happen if they did align.

- It would be significantly more activity, still containable, but I would recommend holding to the staggered start.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Actual Peak</th>
<th>Perfect Storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Page I/Os</td>
<td>4983/second</td>
<td>11,963/second</td>
</tr>
<tr>
<td>Paging MB/second</td>
<td>385 MB/Second</td>
<td>963 MB/Second</td>
</tr>
</tbody>
</table>
Summary

- DS8870 with SSD is providing much better I/O performance characteristics compared to spinning disk.
  - Bonus benefit in Processor resource savings

- The process of restarting 100s of Linux guests impacts paging performance significantly, though the characteristics can be different from high paging rates after the system has stabilized.

- Need to continue to track I/O operations and data rates, as well as the normal performance metrics:
  - Page wait
  - Asynchronous Page wait
  - Available List management

- The need for higher IOPS and bandwidth can be important to z/VM
  - Other limits eliminated
  - Higher consolidation workloads
QUESTIONS & DISCUSSION