IS MLC READY FOR THE ENTERPRISE?

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MEET TOM

38 YEARS OLD, MARRIED, 2 KIDS

DEGREE IN COMPUTER SCIENCE

IT MANAGER AT LARGE DATA CENTER THAT PROVIDES CLOUD HOSTING SERVICES

HAS WORKED HERE FOR 5 YEARS, SLATED FOR PROMOTION TO DIRECTOR OF IT
THE CONNECTED WORLD IS COMPLEX
...AND IT’S GETTING MORE COMPLEX

2005 – 3 PATHS
...AND IT’S GETTING MORE COMPLEX
EXPLODING DATA GROWTH

EVERY MINUTE, 72 HOURS OF VIDEO ARE UPLOADED TO YOUTUBE

EVERY HOUR, ENOUGH INFORMATION IS CONSUMED BY INTERNET TRAFFIC TO FILL 7 MILLION DVDS

EVERY DAY, 247 BILLION E-MAILS ARE SENT

FACEBOOK HANDLES 40 BILLION PHOTOS FROM ITS USER BASE

THE AMOUNT OF INTERNET TRAFFIC WILL REACH 667 EXABYTES ANNUALLY BY 2013
TOM’S NEW ASSIGNMENT

DATA CENTER READINESS FOR INCREASED USER ACCESS AND PERFORMANCE DEMANDS
The demands on the datacenter

By 2014, >50% of all workloads will be processed in the cloud.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cloud Data Center</th>
<th>Traditional Data Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>21%</td>
<td>79%</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>57%</td>
<td>43%</td>
</tr>
</tbody>
</table>
TOM RUNS SOME EXPERIMENTS
JETSTRESS 2010 BENCHMARK

**Hardware Configuration:** IBM System x 3850 x5, 4 x 2.27GHz CPU, and 64GB RAM

**OS:** Windows Server 2008 R2 Enterprise x64

**Application:** Windows Server 2008 R2 Enterprise x64, Jetstress 2010 Database Benchmark
JETSTRESS 2010 BENCHMARK RESULTS

- **I/O Database Reads**
- **Average Latency (ms)**

Achieved Transactional I/O per Second

- HDD (estimated)
- 4x SSD (eXflash)

# of drives

- HDD (estimated)
- 4x SSD

21x Reduction
CLIENT MLC SSDS ARE THE SOLUTION!

TOM REPLACES THE HDDs WITH CLIENT MLC SSDs IN HIS STORAGE RACKS

HIS BOSS PRAISES HIM THAT HE INCREASED COMPUTING POWER WITHOUT INCREASING FOOTPRINT

TOM IS PROMOTED TO DIRECTOR OF IT!
ONE YEAR LATER...

CAN TOM KEEP HIS JOB?
MANAGING ENDURANCE THROUGH ECC

Comprehensive error recovery can lead to performance degradation and latency problems.

TRADITIONAL APPROACH OF ADDING ECC CAPABILITY IS NOT SUFFICIENT
ARE MLC SSDs NOT GOOD ENOUGH FOR HIS ENTERPRISE ENVIRONMENT?
Tom needs to cover a range of applications requirements!
TOM STARTS TO LEARN ABOUT ENDURANCE

MLC, eMLC, SLC, OVERPROVISIONING, DWPD, WRITE AMPLIFICATION....
**SSD TERMINOLOGY**

<table>
<thead>
<tr>
<th>DWPD =</th>
<th>Endurance • (1+OP)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DaysPerLife • WA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OP = Overprovisioning =</th>
<th>Physical Capacity -1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Logical Capacity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WA = Write Amplification =</th>
<th>Data from Host</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data to Flash</td>
</tr>
</tbody>
</table>
WORKLOAD CONTINUUM

A WORKLOAD CONTINUUM REQUIRES AN ENDURANCE CONTINUUM
WORKLOAD CONTINUUM

MLC 1 DWPD
VOD/ Media Streaming

eMLC 10 DWPD
OS boot

SLC 35 DWPD
Exchange Server

Data Warehousing

Virtual Server

Web Server Logging

95/5%
90/10%
70/30%
50/50%
20/80%
0/100%

95/5% 1 DWPD
90/10% 10 DWPD
70/30% 35 DWPD
50/50% 50 DWPD
20/80% 70 DWPD
0/100%

INADEQUATELY SAMPLED ENDURANCE = LOSS OF ??
DISCRETE ENDURANCE OFFERING

The diagram illustrates the relationship between DWPD (5-year Life) and Relative Component Cost (Normalized to MLC). It compares MLC, eMLC, and SLC options, showing how each performs in terms of durability and cost. SLC has the highest DWPD but also the highest cost, making it the most durable option over a 5-year life span. MLC has a lower DWPD and lower cost compared to SLC, while eMLC offers a balance between durability and cost.
FILE SERVER: THE CONSEQUENCE OF DISCRETE ENDURANCE

- **Relative Component Cost (Normalized to MLC)**
- **DWPD (5-year Life)**

- **eMLC**
- **MLC**
- **SLC**

- **Unused endurance**
- **Cost Δ**
- **Required Endurance = 1 DWPD**
- **Insufficient endurance requires multiple drives (TCO)**
### FILE SERVER: MLC OR EMLC?

**90/10% Read/Write**

1 DWPD

<table>
<thead>
<tr>
<th></th>
<th>Entry MLC 200GB</th>
<th>eMLC 200GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Acquisition Cost</td>
<td>$240</td>
<td>$1,000</td>
</tr>
<tr>
<td>Drive writes/day</td>
<td>0.4</td>
<td>7</td>
</tr>
<tr>
<td>Calculated Life (in years)</td>
<td>2.2</td>
<td>30.4</td>
</tr>
<tr>
<td>Replacement rate/year</td>
<td>0.46</td>
<td>0.03</td>
</tr>
<tr>
<td>5 year cost of ownership</td>
<td>$548</td>
<td>$1,000</td>
</tr>
</tbody>
</table>

#### 1 Petabyte Install Base

- **Initial Cost of Drives**
  - Entry MLC: $0
  - eMLC: $1

- **Total Cost of Ownership**
  - Entry MLC: $5
  - eMLC: $4.8

**316%**

**82%**
OLTP: THE CONSEQUENCE OF DISCRETE ENDURANCE

- **Relative Component Cost (Normalized to MLC)**

- **Unused endurance**
  - Required Endurance = 10 DWPD

- **Insufficient endurance requires multiple drives**

---

**DWPD (5-year Life)**

- **MLC**
- **eMLC**
- **SLC**

---

**Relative Component Cost (Normalized to MLC)**
OLTP: SLC OR eMLC?

70/30% Read/Write
10 DWPD

<table>
<thead>
<tr>
<th></th>
<th>SLC 200GB</th>
<th>eMLC 200GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Acquisition Cost</td>
<td>$1,400</td>
<td>$800</td>
</tr>
<tr>
<td>Drive writes/day</td>
<td>25.5</td>
<td>7</td>
</tr>
<tr>
<td>Calculated Life (in years)</td>
<td>12.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Replacement rate/year</td>
<td>0.08</td>
<td>0.3</td>
</tr>
<tr>
<td>5 year cost of ownership</td>
<td>$1,400</td>
<td>$1,182</td>
</tr>
</tbody>
</table>

1 Petabyte Install Base

- Initial Cost of Drives
  - SLC: $7.0 million
  - eMLC: $6.0 million
  - 75% Savings

- Total Cost of Ownership
  - SLC: $7.0 million
  - eMLC: $5.8 million
  - 18% Savings
\[
\frac{\pi^2}{(1+z)^2 \sqrt{1+290^2}} \left\{ 1 + \frac{\partial}{\partial z} \right\} \left( \frac{p + \frac{p_{th}}{c^2}}{r} \right) \leq 0
\]

\[
\text{What if?}
\]

\[
p = \text{Matter density of the Universe}
\]

\[
- \text{Ricci-Flat}
\]

\[
- \text{R tensor proportional}
\]

\[
\lambda = \text{Cosmological constant} / -\Lambda - \text{R}(\mu\nu - t\bar{t})
\]

- Specral

\[
\text{The solution is: } x = \frac{c}{5} (\cos t)
\]

- Length

- Time constant

- Time

- Constant

- Interval

- Appearance

- Longer
...WE CAN CHANGE THE DNA OF MLC NAND?
THEN...

WE CAN ACHIEVE OPTIMAL COST AT EVERY ENDURANCE POINT WITH MLC-EE
FILE SERVER: THE ADVANTAGE OF MLC-EE

- Required Endurance = 1 DWPD
- Unused endurance
- Insufficient endurance requires multiple drives
FILE SERVER: MLC OR MLC-EE?

90/10% Read/Write

<table>
<thead>
<tr>
<th></th>
<th>Entry MLC 200GB</th>
<th>MLC-EE 200GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Acquisition Cost</td>
<td>$240</td>
<td>$300</td>
</tr>
<tr>
<td>Drive writes/day</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Calculated Life (in years)</td>
<td>2.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Replacement rate/year</td>
<td>0.46</td>
<td>0.15</td>
</tr>
<tr>
<td>5 year cost of ownership</td>
<td>$548</td>
<td>$300</td>
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LOSS = MONEY
OLTP:
THE ADVANTAGE OF MLC-EE

Unused endurance
Required Endurance = 10 DWPD
Insufficient endurance requires multiple drives

Relative Component Cost (Normalized to MLC)

DWPD (5-year Life)

Cost Δ
OLTP: eMLC VS MLC-EE

70/30% Read/Write

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<th>Drive Acquisition Cost</th>
<th>Drive writes/day</th>
<th>Calculated Life (in years)</th>
<th>Replacement rate/year</th>
<th>5 year cost of ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>eMLC 200GB</td>
<td>$800</td>
<td>7</td>
<td>3.4</td>
<td>0.3</td>
<td>$1,182</td>
</tr>
<tr>
<td>MLC-EE 200GB</td>
<td>$600</td>
<td>10.2</td>
<td>4.9</td>
<td>0.20</td>
<td>$609</td>
</tr>
</tbody>
</table>

1 Petabyte Install Base

LOSS = MONEY
WORKLOAD CONTINUUM

MLC-EE = ENDURANCE CONTINUUM
THE MORAL OF THE STORY

NO MORE WORRY ABOUT FLASH WEAR OUT AND SYSTEMS FAILING

NO MORE WORRY ABOUT DEGRADING PERFORMANCE

NO MORE WORRY ABOUT HIGH TOTAL COST OF OWNERSHIP

TOM IS KEEPING HIS JOB!
THANK YOU!

SMART STORAGE SYSTEMS™
Making NAND Better