Utilizing Ultra-Low Latency Within Enterprise Architectures

Page Tagizad, Product Marketing - Enterprise Storage Solution

April 22, 2014
Forward-Looking Statements

During our meeting today we will make forward-looking statements.

Any statement that refers to expectations, projections or other characterizations of future events or circumstances is a forward-looking statement, including those relating to market position, market growth, product sales, industry trends, supply chain, future memory technology, production capacity, production costs, technology transitions and future products. This presentation also contains forward-looking statements attributed to third parties, which reflect their projections as of the date of issuance.

Actual results may differ materially from those expressed in these forward-looking statements due to a number of risks and uncertainties, including the factors detailed under the caption “Risk Factors” and elsewhere in the documents we file from time to time with the SEC, including our annual and quarterly reports.

We undertake no obligation to update these forward-looking statements, which speak only as of the date hereof or as of the date of issuance by a third party, as the case may be.
## A Global Leader in Flash Storage Solutions

### Rankings

<table>
<thead>
<tr>
<th>Financials</th>
<th>SanDisk Client &amp; Retail SSDs Approved Supplier to All Leading PC Manufacturers</th>
</tr>
</thead>
</table>

### Trailing 4 Qtr Financials*

<table>
<thead>
<tr>
<th>Financials</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$6.2B</td>
<td>Revenue</td>
</tr>
<tr>
<td>$3.6B</td>
<td>Net Cash*</td>
</tr>
<tr>
<td>$0.7B</td>
<td>R&amp;D Investment</td>
</tr>
</tbody>
</table>

### Global Operations

- **5,500 Employees†**

### Leading Retail Brand*

- **#1 Global Retail Revenue Share**

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*SanDisk Client & Retail SSDs Approved Supplier to All Leading PC Manufacturers*
Enabling Flash Storage from Wafer to Software

Close to Half of Industry Bit Output
Together with manufacturing partner Toshiba*
Fabs: World class NAND capacity

World-Leading Innovator
4,900+ Patents†

* Gartner: NAND Flash Supply & Demand, WW 1Q '12-4Q '14, 3Q '13. Update Dec., '13.
The Path to Ultra Low Latency and Scalable Performance

Latency (µsec)

- DDR: 1s
- PCIe: 10s
- SAS/SATA/FC: 100s
- Flash Storage on the high speed memory bus: 1000s

IOPS

- 100s
- 100,000
- 1,000,000

SanDisk®
Scalable I/O Performance, Constant Latency

![Graph showing scalability and constant latency](image)

- Demonstrated at the Open Compute Summit – Jan 2014
- IBM 3650 2-socket server running Red Hat version 6.3

**Key Points**
- Scalability in I/O performance with constant latency.
- Demonstrated with various ULLtraDIMM™ devices.
- Data shown across different storage capacities: 400G, 800G, 1600G, 3200G.

**Legend**
- (K) IOPS
- Latency (us)

**Graph Details**
- X-axis: Number of ULLtraDIMM™ Devices
- Y-axis: (K) IOPS
- With increasing number of devices, IOPS scale up while latency remains constant.
The World’s First Flash Storage Device on the Memory Channel

- Enterprise Class Reliability, Endurance & Support
- Cost Effective
- Memory Channel Interface
Combining MCS™ and Guardian Technology™ Platform

Guardian Technology™
- Enterprise level endurance with MLC
- 10 drive writes per day
- 5 year warranty

Enterprise Class Reliability
- Back up power circuitry
- Full data path protection
- Enterprise class MTBF

Memory Channel Interface
- DDR3 protocol
- Configured as block device (through device driver)

Ultra Low Latency, High Performance
- Lowest write latency (less than 7 usec)
- Scalable performance by adding additional ULLtraDIMMs

Scalable, Cost Effective Media
- 200, 400 GB
- Scalable architecture
- 19nm flash technology (MLC)

SanDisk
Guardian Technology™ Platform Is a Key Enabler

- Deep Flash Characterization
- Understanding Flash Capability
- Aggregated Flash Management
- Use Each Flash Device to its Full Capability
- Advanced Signal Processing
- Optimizing Flash Settings Over Product Life

19nm MLC NAND

0.5 DWPD

ULLtraDIMM

- Value Based
- High Performance
- High Endurance
- Enterprise Class SSD

Up to 10 DWPD
# ULLtraDIMM Series

## ULLtraDIMM

<table>
<thead>
<tr>
<th>Usage Model</th>
<th>Ultra low latency + scalable IOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>200GB, 400GB</td>
</tr>
<tr>
<td>Form Factor</td>
<td>RDIMM</td>
</tr>
<tr>
<td>Endurance (Random)</td>
<td>10 DWPD</td>
</tr>
<tr>
<td>Warranty</td>
<td>5 years</td>
</tr>
</tbody>
</table>

## Software Drivers

<table>
<thead>
<tr>
<th>Linux RedHat</th>
<th>Linux SuSe</th>
<th>Microsoft Windows</th>
<th>Vmware ESX</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3</td>
<td>SLES 11 SP1</td>
<td>2008R2</td>
<td>5.1U1</td>
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<tr>
<td>6.4</td>
<td>SLES 11 SP2</td>
<td>2012</td>
<td>5.1U2</td>
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<tr>
<td>6.5</td>
<td>SLES 11 SP3</td>
<td>2012 R2</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Utilizing Existing Server Infrastructure

Example: IBM x3850 X6 server

- Scalable up to 32 ULLtraDIMMs
- Up to 12.8TB capacity
- >4.5M IOPS in a single server
Customer Validation

Near Linear Scaling

Lower is better

Source: IBM Redpaper 'Benefits of IBM eXFlash Memory Channel Storage in Enterprise Solutions'; Author: Ilya Krutov; February 24, 2014; IBM form# REDP-5089-00
## Benefits to Applications

<table>
<thead>
<tr>
<th>Financial Services</th>
<th>Database/Cloud</th>
<th>Virtualization</th>
<th>Blade Server</th>
<th>In Memory Compute</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Block device</td>
<td>- Block device/ memory extension*</td>
<td>- Block device</td>
<td>- Block device</td>
<td>- Memory extension*</td>
</tr>
<tr>
<td>- Low, predictable latency</td>
<td>- Increase transactions per second</td>
<td>- Increased VMs per node</td>
<td>- Utilizes empty DIMM slots</td>
<td>- Reduce response times for analytics queries</td>
</tr>
<tr>
<td>- Fast interactive data analysis</td>
<td>- Memcached consolidation</td>
<td>- Faster response times per VM</td>
<td>- Enables high density storage blades</td>
<td></td>
</tr>
</tbody>
</table>

* Future roadmap

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SNIA Data Storage Innovations – April 22, 2014
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## Benefits to Applications

<table>
<thead>
<tr>
<th></th>
<th>Latency Sensitive</th>
<th>Write Intensive</th>
<th>Read Intensive</th>
<th>Bandwidth Intensive</th>
<th>IOPS Intensive</th>
<th>Good for ULLtraDIMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLTP database</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>No SQL database</td>
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<td>✓</td>
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<td>Virtual desktop</td>
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<td>✓</td>
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<td>High frequency trading</td>
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<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

- Lowest latency SSD solution in the market
- Near linear scalability in IOPS and bandwidth w/ parallel processing architecture

Source: IBM Redpaper * Benefits of IBM eXFlash Memory Channel Storage in Enterprise Solutions*; Author: Ilya Krutov; February 24, 2014; IBM form# REDP-5089-00
Reduced Latency Enables Real-Time Analytics

Latency (usec)

AMPS Messaging Suite by 60 East

Low Latency, Predictable Performance will win the trade

50/50 Log/Playback

Summary

- First enterprise-class SSD that utilizes the memory bus
- ULLtraDIMM takes advantage of the ultra-fast memory bus lanes
- Lowest write latency SSD in the market
- Parallel architecture allows high IOPS and bandwidth performance
Thank You