Green Memory Solution

Jung-Bae Lee
Contents

• Introduction
  – Data Explosion and Data Center Expansion
  – Data Center Issues: Power & Performance

• Samsung “Green Memory” Solution
  – History of “Green Memory”
  – Memory & Storage: DDR4 DRAM & NVMe PCIe SSD
  – TCO Savings and Benefits of Samsung Solution
  – Future Memory and Storage
Data Trends in Data Centers

- Paradigm shift from Web 2.0 to Web 3.0 triggered exponential data increase
Growth of Data & Data Traffic

- World-wide Volume of data expected to double every 1.2 years
- 125% annual increase of data traffic handled by data center

Data Growth

Data Traffic Growth

[Images of bar charts showing data growth and traffic growth over years from 2012 to 2020. Sources: Oracle, 2013; Cisco, 2013.]
Data Center Expansion

- Data center revenue will reach $20B by 2016
- Strong storage volume demand accordingly (over 150 EB by 2016)

Data Center Revenue Forecast

- CAGR: 36%

Data Center Storage Forecast

- CAGR: 47%

[ Gartner, 2013 ]
[ 451 Research, 1Q'2013 ]
Issues with Data Traffic in Data Center

- Wide disparity between data traffic and data center infrastructure
  - 3.7X data traffic increase but space and server/storage spending only projected to 1.7X and 1.2X increase

<table>
<thead>
<tr>
<th>Year (2011-2016)</th>
<th>Traffic Data in DC (Zettabytes)</th>
<th>Datacenter Capacity (M SF)</th>
<th>Server/Storage Spending (B$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>1.8 ZB</td>
<td>$888</td>
<td>$1098</td>
</tr>
<tr>
<td>2012</td>
<td>2.6 ZB</td>
<td>$908</td>
<td>$1031</td>
</tr>
<tr>
<td>2013</td>
<td>3.3 ZB</td>
<td>$948</td>
<td>$1002</td>
</tr>
<tr>
<td>2014</td>
<td>4.1 ZB</td>
<td>$996</td>
<td>$996</td>
</tr>
<tr>
<td>2015</td>
<td>5.2 ZB</td>
<td>$1038</td>
<td>$1009</td>
</tr>
<tr>
<td>2016</td>
<td>6.4 ZB</td>
<td>$1098</td>
<td>$1098</td>
</tr>
</tbody>
</table>

[Reference: IDC’s Data center Census, ’12 / Gartner ‘13]
Key Concerns and Movements

- Data center CIOs’ (Chief Information Officer) 4 major problems

  - **POWER**: Required power supply for maintaining and operating data centers
  - **SPACE**: Insufficient space for housing the increasing amounts of data
  - **BUDGET**: Limited budget for maintenance
  - **MANAGEMENT**: Management as overall operational and security issues

- Data center industry’s movements to solve issues
  - Location, Location, Location: Cooler climate & low $ real estate
  - Maximizing server efficiency with virtualization (Key technology breakthrough)

Source: SAMSUNG Memory Solutions Forum 2013
Power in Data Center

- Power-related cost occupies 31% from total data center cost
- Memory & Storage power portion including cooling takes 32% of total data center power

![Data Center Cost Portion](Source: http://perspectives.mvdirona.com/2010/09/18/OverallDataCenterCosts.aspx)

![Memory Power Portion](Source: Uptime Institute's 2013 Data Center Survey, SAMSUNG, EMC)

*PUE : Power Usage Efficiency

[Worldwide Average PUE*: 1.65]
Memory Power Portion in Data Center

- Memory power portion of data center getting more importance
  - On-going effort for better PUE (Power Usage Efficiency)
  - Consequently, better PUE to make relative increase in memory power portion
    (19% with PUE 1.65 → 27%* with PUE 1.2)

[World wide average PUE* : 1.65]

Source: Uptime Institute 2013 Data Center Survey, SAMSUNG, IDC, EMC

*PUE (Power Usage Efficiency) = Total facility power \( \frac{\text{IT equipment power}}{\text{IT equipment power}} \) → Ideal PUE is 1.0 if others is zero.
Virtualization as key technology for TCO (Total Cost of Ownership) reduction, requiring more performance from H/W to handle more data.

<table>
<thead>
<tr>
<th>Typical Server Usage</th>
<th>Optimized for Virtualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDD</td>
<td>IOPS: &lt; 400</td>
</tr>
<tr>
<td></td>
<td>Latency: &gt; 50ms</td>
</tr>
<tr>
<td>DDR3</td>
<td>Performance: 1x</td>
</tr>
<tr>
<td>Power</td>
<td>1x</td>
</tr>
</tbody>
</table>

H/W Traffic

More H/W Traffic

Typical Server

Server with Virtual Machine

Application

Operating System

Hypervisor (Virtualization)

Hardware

Typical Server

Server with Virtual Machine

Application

Operating System

Hypervisor (Virtualization)

Hardware
Let There Be Right Solution

with Samsung Green Memory Solution – DDR4 DRAM & NVMe PCIe SSD
Since 2009, Samsung has been creating generations of “Green Memory” solution every year.
• Samsung’s world best DRAM and SSD products leading the market
39% system performance improvement and 15% memory power reduction compared to existing DDR3 technology (1600Mbps, 1.35V → 2133Mbps, 1.2V)

* Benchmark result (16GB 2DPC@DDR3 1.35V, DDR4 1.2V)
Samsung Green Memory - DDR4 DRAM (2)

- More reliability features compared to DDR3
- Samsung’s In-DRAM solution is the most efficient for Row Hammer operation

**Enhanced Reliability**

- PPR
- CRC
- CA Parity
- PDA Mode
- DBI
- LRDIMM
- Parity RDIMM
- Data ECC

**Row Hammer Free**

- [ Better Performance ]
  - pTRR + 2x Ref
  - In-DRAM (Samsung)

- [ Less Power ]
  - pTRR + 2x Ref
  - In-DRAM (Samsung)

* PPR (Post Package Repair), CRC (Cyclic Redundancy Check), CA (Command, Address) Parity, PDA (Per DRAM Addressability), DBI (Data Bus Inversion)

* pTRR: Pseudo Target Row Refresh
* Condition: 3DPC & > 32GB/Ch.
NVMe PCIe provides superb bandwidth through multi-lane architecture, and better latency from efficient protocol and simple architecture.

- Bandwidth Improvement: +567%
- Latency Improvement: +67%
• NVMe PCIe SSD provides significant energy efficiency (x2000 compared to SATA HDD)

- Low-power NAND
- Low-power Controller
- Low-power PCB/Circuits

Power: considered with 8 hours active and 16 hours idle status
Performance: workload considered with 7:3 read/write ratio

6 Watt
2 Watt

2,000x
Energy Efficiency (IOPS/Watt)

SATA HDD
NVMe PCIe

200 IOPS
140K IOPS

3x better in Power
700x better in Performance
TCO savings – ‘Green Memory’

- ‘Green memory’ can dramatically reduce TCO (Total Cost Ownership)
- Better performance, less power and space with same cost

**Existing Server**

- Concurrent Users (1K people): 40,000
- Power Consumption (KW): 2,600
- Server (EA): 10,000

**“Green Memory” Server**

- Concurrent Users (1K people): 65,000
- Power Consumption (KW): 2,300
- Server (EA): 7,800

Source: SAMSUNG Green Memory - Official Website
Benefits from Samsung Solution

- TCO savings translated to increase in data center capacity and investment → 3.4X improvements in space, 2X in server/storage

[Reference: IDC ’12 / Gartner ’13 / Samsung]
Samsung 5th generation ‘Green Memory’ solution saves 3.1 billion dollars, equivalent to 45TWh energy savings.

* Assumes ‘14 W/W Server & high-end storage change to 100% Green Memory
Future Technology - DRAM

- Samsung keeps leading process technology innovation

- TSV* for high capacity with low power, HBM* for high BW with low power

Now

- 20nm process
- 1xnm process
- 1ynm process

4H TSV Stack DRAM
- Upto 128GB capacity module (with 8Gb comp.)

HBM
- 8Channel
- 1024 I/O (128Bit per Channel)
- 256GB/s (2Gbps per Pin)
- 2/4/8H TSV Stack

* TSV: Thru Silicon Via, HBM: High BW Memory
Future Technology - SSD

- NAND scale-down to be continued with V-NAND technology
- Innovative features to be introduced with next generation SSDs

SSD with V-NAND

<table>
<thead>
<tr>
<th>Planar NAND</th>
<th>V-NAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantage</td>
<td>Easy to produce with simple process</td>
</tr>
<tr>
<td>Challenge</td>
<td>Shrinking under sub-10nm</td>
</tr>
</tbody>
</table>

New Features

- Key_Value Storage
- In Storage Processing

Key_Value Communication

Object Storage

Database

Processing Distribution...
Future Memory

- On-going technology innovation keeping up DRAM & NAND scale-down
- New memory solutions under development for future value creation

Performance vs. Cost

- DRAM
- MRAM
- PRAM
- NAND
- ReRAM

- Storage Class Memory @ Server
- Unified memory @ IoT
- Large size storage
- Embedded memory @SoC
- Unified memory @ IoT

Performance vs. Cost Matrix:

- Performance: Low to High
- Cost: Low to High
- Maturity: Low to High
Summary

- Samsung’s world best DRAM and SSD products are leading the market

- Samsung has been creating generations of “Green Memory” solution every year since 2009

- Samsung ‘Green memory’ can dramatically reduce TCO (Total Cost of Ownership)
  - DDR4 DRAM offers 39% improved performance and 15% reduced power compared with DDR3
  - NVMe PCIe SSD offers 2,000x better energy efficiency than SATA HDDs

- Future technology developments are on track
  - DRAM & NAND keep shrinking with process technology innovation
  - New features are going to be introduced with next generation SSDs
  - New memory technologies (MRAM/PRAM) are under development as value creation products
Thank You