Modeling the Implications of DRAM Failures and Protection Techniques on Datacenter TCO

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MICRO 48, Waikiki, Hawaii, December 5th 2015
Today’s Datacenters

> 510,000 DC in all over the world [Emerson, 2011]

> 285 Million Sqft [Emerson, 2011]

Large scale Datacenters: >10,000 commodity servers

Many Million $ per month
Datacenter Cost

[Analysis using COST-ET tool, D. Hardy 2013]

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DRAM Protection Cost

[Analysis using COST-ET tool, D. Hardy 2013]

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Do we need DRAM protection?

- Google Failure Study [Barroso, 2009]
- DRAM large field studies [V. Shridharan 2012, 2013]

DRAM protection is essential !!
DRAM protection choices

<table>
<thead>
<tr>
<th></th>
<th>ChipkillDC</th>
<th>ChipkillSC</th>
<th>SECDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Reliability</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Performance</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
</tbody>
</table>
DRAM protection selection

*Analyzer of Memory Protection and Failures Implications on TCO (AMPRA tool), site: http://www2.cs.ucy.ac.cy/carch/xi/ampra_tco.php
Our Proposition & our Contribution

AMPRA tool

- DIMM FIT Model
- DRAM SDC Model
- Availability/MTTF Model
- Energy Model
- Thermal Model
- DIMM Cost Model
- Server Performance Model
- TCO Model

Best DRAM Protection Technique

- Performance
- Reliability
- Power
- Application Characteristics
- Error protection techniques

Related work

• [Y. Luo DSN 2014] Proposes and analyzes cost of a heterogeneous memory protection scheme

Differences:

– Performance, power implications of memory protection techniques

– Co-located services

– Datacenter cost

• No other related work considers various parameters
Outline

• Proposed Framework (AMPRA tool)
• Use Case
• Experimental Framework
• Results
• Conclusions
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Use Case

Bandwidth vs. Latency vs. Reliability vs. Power
Chipkill with Dual Channel Implementation (ChipkillDC)
Chipkill with Single Channel Implementation (ChipkillSC)
16 ECC bits for 128 Data bits-144 bit codeword
FIT model

• ChipkillDC:
  – Detects all the errors in 2 devices
  – Corrects all the errors in 1 device

• ChipkillSC:
  – Cannot detect all the errors in 2 devices
  – Corrects all the errors in 1 device

ChipkillDC can provide better Reliability than ChipkillSC
Performance and Power model

How it works: (ChipkillDC)

- Read

• Requires accessing two DIMMs
• Codeword in a single burst
• Latency short 😊
• Low Bandwidth 😞
• High Power Consumption 😞
Performance and Power model

How it works: (ChipkillSC)

- Read

64B Block

• Requires accessing one DIMM
• Codeword in two bursts
• Latency long 😞
• High Bandwidth 😊
• Less Power Consumption 😊
### Design Space

<table>
<thead>
<tr>
<th></th>
<th>ChipkillSC</th>
<th>ChipkillDC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reliability</strong></td>
<td>Cannot detect all the errors in 2 devices</td>
<td>Detect all the errors in 2 devices</td>
</tr>
<tr>
<td></td>
<td>Corrects all the errors in 1 device</td>
<td>Corrects all the errors in 1 device</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td><img src="https://example.com/checkmark" alt="✓" /> Access one DIMM</td>
<td><img src="https://example.com/x" alt="✗" /> Access two DIMMs</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td><img src="https://example.com/x" alt="✗" /> Codeword in two bursts</td>
<td><img src="https://example.com/checkmark" alt="✓" /> Codeword in one burst</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td><img src="https://example.com/checkmark" alt="✓" /> Access one DIMM</td>
<td><img src="https://example.com/x" alt="✗" /> Access two DIMMs</td>
</tr>
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</table>

What happens with the Cost?

- **Application characteristics**
  - Memory intensive, compute intensive
  - Co-running applications
Online and Offline Services

Online Services: High QoS requirements

Offline Services: Do not have QoS constrains

Co-location: Improve server utilization and reduce TCO
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Experimental Framework

**Performance, Power and Thermal Model**

- **ChipkillDC** - Lockstep Mode
  - Server Configuration: Intel Xeon E5-5620
  - 4 cores per CPU
  - 2 channels per CPU
  - 1 DIMM per Channel

- **ChipkillSC** - Advance Mode

**Workloads**

1. Web Search (QoS requirements)
2. MapReduce:
   - 500MB (CPU intensive)
   - 49000MB (memory intensive)

**DIMM Cost**

- Public Data

**Fit Model**

- Analytical Models

**DC Configuration**

- Server Modules: 50,000
- DC depreciation: 15 year

**TCO Model**

- Extension COST-ET Tool [D. Hardy 2013]

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**Graphical Data**

- **WS alone**
- **WS +1 MR500**
- **WS +1 MR49000**

**Legend**
- **ChipkillSC**
- **ChipkillDC**

**Label**
- Average Search time (ms)

**Cases**
- WS: Web Search
- MR500: Map Reduce 500MB
- MR49000: Map Reduce 49000MB

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DRAM Protection Implications on Power

WS: Web Search
MR500: Map Reduce 500MB
MR49000: Map Reduce 49000MB
• **Underlines the importance of understanding the usage and characteristics of all the services to be run in a DC before making memory protection design choices**

• **Highlights the need of proposed framework !!**
Usage

• **Datacenter designers:** Select processor and protection technique

• **Researchers:** Investigate the implications of new ideas related to DRAM failures and DRAM protection techniques

• **Service providers:** Find how to charge for running offline services and to makeup for the increase in TCO due to co-location
More in the paper

• Detailed explanation of each model

• DRAM grades and how affect TCO

• Results for other protection techniques (SECDED)

• Power and performance results for more applications
Conclusions

• DRAM is one of the dominant cost consumers in a DC

• Different protection techniques have different TCO implications

• Framework to encapsulates all the parameters and tries to determine the cost-effective protection technique for a DC

• Highlight the need of the framework
  – It is not straightforward to decide which DRAM protection technique is best for a DC setup in the lack of this framework
Future Work

• Evaluate TCO for more online and offline services

• Explore the cost-benefits of new ECC schemes

• Validation of the framework by using detailed logs from a real DC
Thanks!

MAHALO!

AMPRA tool download site:
http://www2.cs.ucy.ac.cy/carch/xi/ampra_tco.php