maxCache 4.0 SSD Read and Write Caching Solutions

White Paper

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EXECUTIVE SUMMARY

Today's data centers and cloud computing environments require increased I/O performance and decreased latency in order to support large-scale applications such as web serving, file serving, databases, online transaction processing (OLTP), Microsoft Exchange Server, and high performance computing (HPC). This white paper focuses on the performance benefits of using Microchip's Adaptec maxCache 4.0 Solid State Drive (SSD) Caching Solutions for key data center applications and the cost savings that can be realized from this improved application performance.

In terms of I/O performance and average latency, SSDs can deliver up to a 1000x performance gain over Hard Disk Drives (HDDs) in random-access read and write operations. maxCache leverages those benefits by using SSDs to cache copies of frequently-accessed (aka "hot") data for both read and write workloads.

The performance and financial benefits of maxCache 4.0 are illustrated in this paper by comparing the performance levels in 100% Random-Read and Write IOmeter workload scenarios with a maxCache 4.0-enabled Microchip Adaptec RAID adapter vs. the same adapter without maxCache 4.0 enabled. These quantified performance improvements can be applied to a Total Cost of Ownership (TCO) calculation summarizing the potential savings in Capital Expenses (CapEx) and Operating Expenses (OpEx).

PERFORMANCE HIGHLIGHTS

Accelerating application performance, reducing latency, and increasing the number of users supported per server are key requirements for data centers and cloud computing environments.

Benchmark tests designed to illustrate the theoretical maximum benefits of maxCache 4.0 examined a scenario where all data was delivered by the maxCache SSD cache at varying cache hit rates and compared the results to those of an HDD-only RAID array of twenty 7200 RPM SATA HDDs. The 100% cache hit rate comparison showed:

- Up to 8x performance improvement in read-intensive IOPS in a RAID 50 configuration
- Up to 36x performance improvement in write-intensive IOPS in a RAID 50 configuration

In a typical real-world environment where the maxCache scenario incorporates data delivered by both the SSDs and HDDs, the maxCache solution still delivered substantial benefits over the HDD-only array. The 50% cache hit rate comparison showed:

- Up to 2x performance improvement in read-intensive IOPS in a RAID 50 configuration
- Up to 2x performance improvement in write-intensive IOPS in a RAID 50 configuration

INTRODUCTION

Data centers and cloud computing environments require application-tuned, high-density servers to provide end-users with consistently high quality of service (QOS). Usually, these server deployments are targeted towards specific applications such as web serving, file serving, databases, OLTP, Microsoft Exchange Server, and HPC. Customers of these data centers and cloud computing applications typically sign service level agreements (SLAs) that obligate the operators to provide pre-determined levels of reliability, availability, and serviceability (RAS) as well as performance. To meet these requirements, data center operators deploy servers with high I/O throughput and high IOPS that are "application-tuned" to ensure adherence to the SLA. Violating the SLA terms can lead to severe financial penalties for the data center operator, not to mention the adverse customer reaction to any unsuitable performance or user experience.

In addition to SLA requirements, budgets compel data centers to increase the number of hosted users per server in order to reduce the cost of service (COS) per user as well as the CapEx and OpEx of additional hardware.

Adding more end-users to a server will cause an increase in latency and a decrease in IOPS per user. Since both of these issues happen well before storage capacity is maxed out, data centers and cloud computing environments are forced to add new servers to maintain appropriate levels of service, even if the existing servers have the storage capacity for more users. This results in low storage capacity utilization and an increase in CapEx and OpEx (namely maintenance, power and cooling costs), as well as an increase in physical space requirements.

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Additionally, to meet the fast response time and availability requirements of the SLA and increase the number of hosted users required for reducing the COS, operators tune servers to pool data in the system cache despite the fact that not all data is accessed by users uniformly. Web servers, for example, pool homepages of the websites they host much more frequently than other pages.

E-commerce applications query images of frequently-accessed ("hot") products much more often compared to other ("cold") products, and also sell these "hot" products more often.

But it is not just the SLA that is at stake. Increasingly, end users and customers are becoming less tolerant of latency and poor IOPS performance. According to Equation Research:1

• 78% of site visitors have gone to a competitor's site due to poor performance during peak times.
• 88% are less likely to return to a site after a poor user experience.
• 47% left the site with a less positive perception of the company.

A poor-performing website can have quantified financial implications. Amazon found that 0.1 seconds of latency shaves 1% from sales revenues, for example.[1] Companies that address the latency challenge have reaped rewards. Shopzilla, for example, reports that improving website performance by five seconds led to 25% more page views and a 12% revenue increase; large financial institutions leverage a 0.5-second speed advantage to execute millions of orders-per-second and make record profits.

Technology that can provide fast responses for "hot" data while maintaining a large capacity of "cold" data will result in direct savings in the number of servers deployed. In other words, any improvement in the servers' I/O capability increases the number of users per server and lowers the cost per user. A technology that can deliver this improved performance while also increasing available server capacity will improve the cost per user and user per server metrics even further.

Microchip's Adaptec maxCache 4.0 SSD Caching meets the needs of I/O-intensive data center and cloud computing environments by allowing them to convert industry-standard servers into cost-effective, high-performance, scale-out application storage appliances that optimize critical usage, performance, and financial metrics.

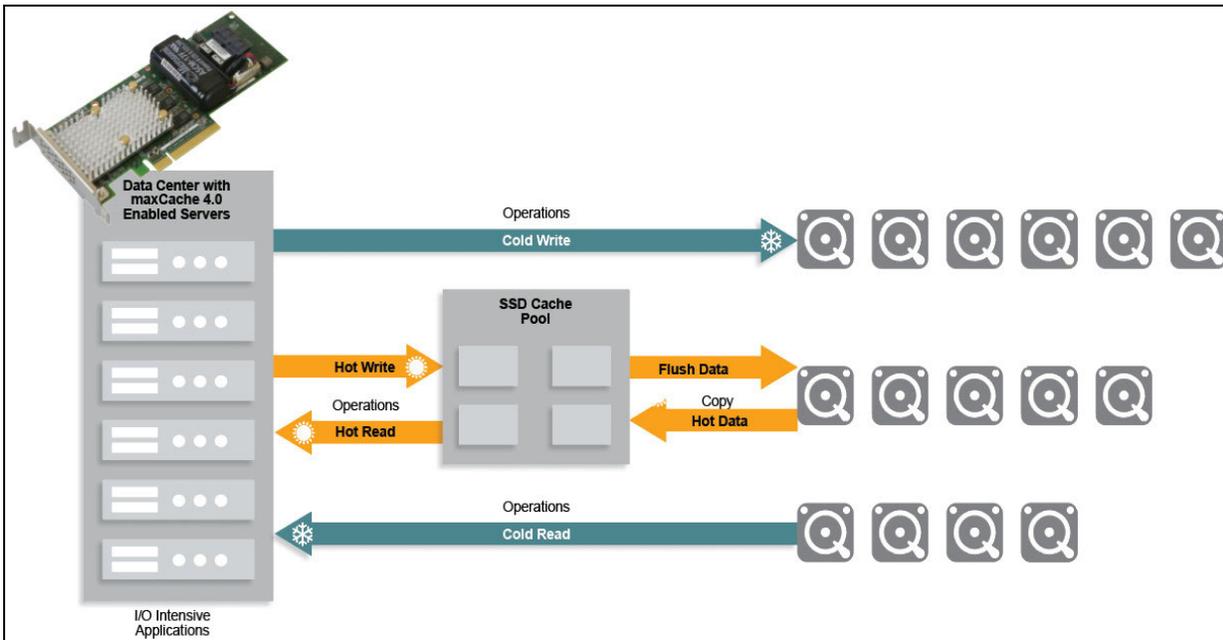1."When more Website visitors hurt your business: Are you ready for peak traffic?," Equation Research 2010.

FIGURE 1: *Adaptec maxCache 4.0 Deployment*

ABOUT MAXCACHE SSD CACHING SOLUTIONS

Adaptec maxCache combines SSDs used as cache with Microchip's maxCache SSD Caching software to dramatically accelerate I/O performance and reduce costs without disrupting existing operations. It virtually eliminates the bottleneck that can occur between CPUs, memory and storage.

SSDs offer a number of advantages compared to HDDs, including higher read bandwidth, higher IOPS, better mechanical reliability (due to the absence of moving parts), and higher resistance to shocks and vibrations. However, the same features (i.e., flash) that provide these advantages also come with some inherent limitations compared to HDDs, such as limited capacity. An SSD's lifespan is also highly dependent on the number of write operations performed to the device.

To capitalize on the advantages of SSDs while suppressing their limitations, maxCache SSD Caching delivers performance benefits for both read and write operations. Adaptec maxCache uses an advanced algorithm which identifies frequently-accessed data and optimizes reads and writes by moving a copy of this data directly into an SSD cache for faster retrieval of future requests. Storing only the "hot" data in the SSD cache optimizes the balance of SSD performance and capacity. By leveraging its unique presence in the data path to create a "cache pool" of "hot" data, maxCache 4.0 SSD caching can provide significant performance gains compared to HDD-only deployments (Figure 1).

Advancements in maxCache 4.0 have added the capability to support up to 32 cache pools to provide greater configuration flexibility. The aggregate size of all cache pools can be up to 6.8 TB. This allows the SSD cache to cover larger hot spots.

Adaptec maxCache 4.0 write-through supports only non-redundant cache pool (RAID0). In this case, an SSD failure will not impact data availability as long as the HDDs are configured in a redundant RAID since all data is still securely stored on the HDD RAID.

maxCache 4.0 supports write-back caching. By caching writes to a redundant SSD cache pool (either RAID 1 or RAID 5), maxCache 4.0 leverages the performance and latency capabilities of SSD technology for both read and write workloads. Note with write-back caching, failure of SSD in a non-redundant configuration (RAID 0) will cause data loss.

By expanding the use of SSD caching, maxCache 4.0 is suitable for wide scale data center deployments, offering increased financial benefit while streamlining hardware design and implementation.

maxCache 4.0 vs. Standard SSDs and PCIe-based Flash Cards

Flash-based storage devices are becoming more affordable and prevalent in computing environments, but they should not be confused with maxCache 4.0 solutions.

In order to get maximum performance when using a standard SSD or a PCIe-based flash card, applications must be tuned to store data that requires higher IOPS on the high-performance SSD or flash. This requires an administrator to have intimate knowledge of that specific application to manually tune it to route certain data to the SSDs.

maxCache eliminates this manual application-specific tuning by automatically and transparently analyzing and routing the read and write data.

Additionally, maxCache 4.0 offers flexibility that PCIe-based flash cards do not. With maxCache 4.0, the end-user can install an SSD with performance metrics and write endurance best suited for the application. Conversely, if an administrator tunes an application to take advantage of SSDs plugged into the motherboard, the SSDs are managed as separate storage and another means to ensure redundancy is needed, which consumes host CPU compute bandwidth.

Recommended SSDs for maxCache 4.0

Due to the sheer volume of data being written to the SSDs in write-caching scenarios, enterprise SSDs are recommended for use with maxCache 4.0. Compared to the client class SSDs that can be found in personal systems such as ultrabooks, laptops and desktop computers, enterprise class SSDs offer superior write endurance (the number of write cycles a block of flash memory can accept before it becomes unusable), support heavier write activity (assume 24 hours per day every day for a data center vs. 8 hours on weekdays for an employee's personal computer), and function in more extreme environmental conditions.

MAXCACHE 4.0 SSD

TEST METHODOLOGY

IOmeter was used to measure the performance benefits of maxCache 4.0 SSD Caching Solutions by comparing the base combination of a Microchip Adaptec SmartRAID 3100 Series Controller and HDDs to the same combination with SSDs and maxCache added.

Tests were run in a 100% read-only and 100% write only workload scenario with data working set size varied to create cache hit rates from 0-100%.

PERFORMANCE

Read Caching Performance — RAID 50

In RAID 50, maxCache yielded a greater than 8x increase in IOPS compared to HDD-only arrays (Figure 2).

- RAID 50 performance comparison under 100% Random Read IOmeter workload.
- HDD-only configuration: Twenty 7200 RPM 6 Gbps SATA HDDs, in RAID 50.
- maxCache 4.0 configuration: Twenty 7200 RPM 6 Gbps SATA HDDs, four 12 Gbps SATA SSDs, in RAID 10.
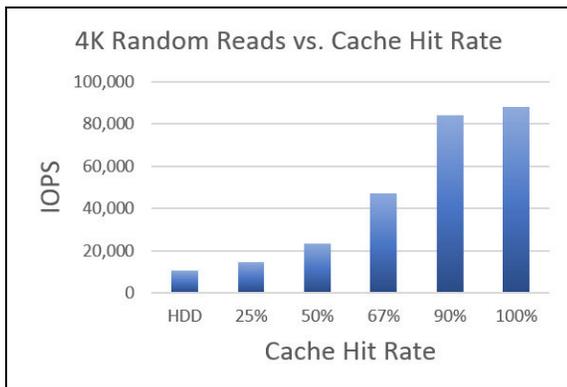
FIGURE 2:   *8x Increase in IOPS with max-Cache 4.0*

Write Caching Performance

Improved write caching support extends maxCache 4.0 benefits to I/O-intensive applications with mixed workloads, including OLTP, Microsoft Exchange Server, and HPC environments. Enabling maxCache 4.0 in these scenarios delivers substantial performance benefits while also allowing for a server design requiring fewer HDDs to achieve the desired performance level. These performance gains were achieved by changing the existing high-capacity HDD server configuration to a maxCache 4.0 configuration comprised of the same type HDDs plus a small number of low-cost SSDs to transparently increase performance.

Write Caching Performance — RAID 50

In RAID 50, maxCache yielded a greater than 36x increase in IOPS compared to HDD-only arrays (Figure 3).

- RAID 50 performance comparison under 100% Random Write IOmeter workload.
- HDD-only configuration: Twenty 7200 RPM 6 Gbps SATA HDDs, in RAID 50.
- maxCache 4.0 configuration: Twenty 7200 RPM 6 Gbps SATA HDDs in RAID 50, four 12 Gbps SATA SSDs, in RAID 10.
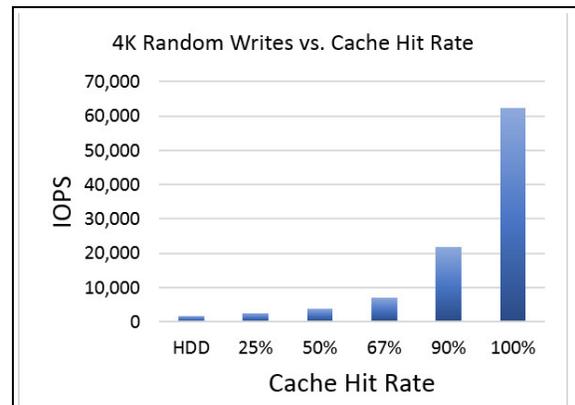

FIGURE 3:   *36x Increase in IOPS with max-Cache 4.0*

IMPACT AND SAVINGS

Real-World Cost-Savings

By accelerating IOPS and reducing latency, maxCache 4.0 allows data center and cloud computing environments to host more users and perform more transactions per second while reducing the overall number of servers required to fulfill any given workload. This reduces a company's CapEx significantly, leading to improved utilization of hardware as well as a reduced server footprint requirements within a data center.

The reduction in servers has an additional financial benefit of reducing the associated OpEx of power, cooling, and maintenance, delivering a highly-reduced TCO solution (Figure 3). OpEx reductions are a continued savings throughout the server lifespan, so the longer the server is in use, the greater the accumulated OpEx will be.

Mixed Workload Environments

In mixed workload RAID 50 scenarios, the real-world performance improvements presented earlier show that maxCache 4.0 delivers 36x greater IOPS for Writes and 8x greater IOPS for Reads than HDD-only arrays. In a blended workload of 67% Reads and 33% Writes maxCache can deliver more than 10x greater IOPS. Therefore, maxCache 4.0 allows data center and cloud computing environments to host the same number of users and perform the same number of transactions per second on a reduced hardware infrastructure as compared to its current HDD-only server infrastructure.

These performance gains significantly reduce a company's CapEx significantly, leading to improved utilization of hardware as well as reduced server footprint requirements within a data center.

The reduction in servers has an additional financial benefit of reducing the associated OpEx of power, cooling, and maintenance, delivering a highly-reduced TCO solution (Figure 4). OpEx reductions are a continued savings throughout the server lifespan, so the longer the server is in use, the greater the accumulated OpEx will be.

Traditional Method

9 servers, 1 rack
200 SATA HDDs
$174,000* System Cost
$196,000** 4 year OPEX cost

maxCache 4.0 Enabled Method

1 server, 1 rack
20 SATA HDDs, 4 SAS SSDs
$25,000* System Cost
$28,000** 4 year OPEX cost
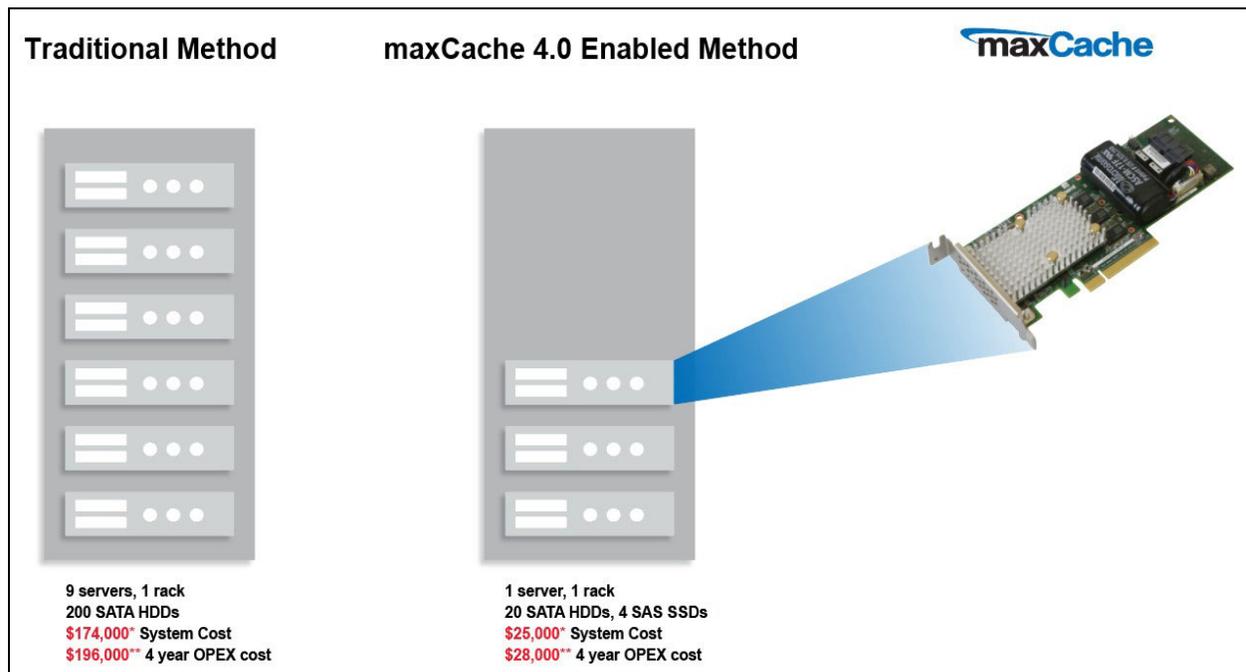
FIGURE 4: *Qualified Impact on Utilization of Hardware Investment*

NOTES:

* Using an estimated unit H/W cost of $3,500 per rack, $10,000 per server, $1000 per SSD, $400 per HDD and zero S/W license fees.

** Using system Power Estimator @800W per server, and a National DOE average of $0.11 per kWH.

Figure 4 illustrates an example where a single server using maxCache with 20 SATA HDDs and 4 SAS SDDs would require 9 servers with more than 200 HDDs to achieve equivalent IOPS.

MAXCACHE 4.0 SSD

Given the performance gains demonstrated above, it may seem preferable to build an SSD-only RAID array instead of a mixture of SSDs and HDDs. Keep in mind, however, that standard SSD storage capacities are still relatively small compared to those of HDDs, making their cost per GB much higher. Adding too many SSDs would significantly increase CapEx.

maxCache 4.0 delivers an optimized balance of SSD performance and HDD capacity to solve the unique challenges faced by data centers and cloud computing operators. With maxCache 4.0 SSD Caching, a data center can still benefit from the larger capacities of rotating media (HDDs), while gaining the improved I/O performance benefits of SSDs.

CONCLUSION

Data center operators and cloud applications are continuously challenged to improve server performance to keep up with the demands of high-throughput applications and growing user bases.

At the same time, space restrictions, power and cooling limitations require data centers to find the most cost-, space-, and energy-optimized products to enhance the server's I/O and workload capability.

As highlighted in the tests above, maxCache 4.0 alleviates latency and I/O bottlenecks by providing up to 36x better server performance for web server and e-commerce applications. This performance potential allows data centers to substitute one maxCache 4.0-enabled server solution for nine "standard" servers and greatly reduce their CapEx and OpEx.

Microchip delivers innovative solutions with SmartRAID products that provide exceptional performance by intelligently routing, optimizing and protecting data as it moves through the I/O path.

With maxCache 4.0 SSD Caching, Microchip addresses the business challenges of next-generation data centers and continues to enable the expansion of cloud computing while minimizing environmental and financial costs.

KEY BENEFITS OF MAXCACHE 4.0

Microchip Adaptec SmartRAID Storage Controllers with maxCache 4.0 SSD Caching provide the following benefits:

- Up to 36x faster than HDD-only solutions: maxCache 4.0 SSD Caching software improves application performance by copying this data directly into an SSD cache pool for faster retrieval in future requests.
- Capability to deploy write caching: maxCache 4.0 SSD Caching software offers write caching capability for expanded application workload benefits. maxCache 4.0 utilizes the write performance benefits of SSDs to provide additional workload performance advancements.
- Reduced capital and operating expenses: maxCache SSD Caching reduces capital expenses by increasing IOPS with less hardware — thereby significantly cutting operating expenses related to energy and maintenance.
- Reduced cost and increased flexibility for SSD selection: Microchip Adaptec SmartRAID Storage Controllers with maxCache 4.0 SSD Caching allows the use of any enterprise class SSD as a cache, allowing a wide range of vendors and lower cost. These controllers have been qualified with some of the most recent enterprise SSD products to leverage improved performance as well as enterprise features and durability.

APPENDIX A: REVISION HISTORY

Revision A (April 2020)

Initial release of this document.

MAXCACHE 4.0 SSD

NOTES:

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