#213154

October 2013

Commissioned by
Fusion-io, Inc.

Fusion ioControl n5 Hybrid Storage Architecture

Performance Comparison versus Conventional NVRAM+SSD+Disk Architecture

EXECUTIVE SUMMARY

Conventional hybrid storage solutions use NVRAM (non-volatile RAM/flash) to cache data before writing to disk, then augment performance with an SSD read cache. While such solutions generally offer acceptable performance for small datasets, they are ultimately limited by the configuration and number of SSDs that can be deployed. In contrast, a hybrid storage approach can leverage PCIe-based flash to provide better performance. This not only provides direct (non-SATA/SAS) access to block-level storage and fast read/write caching, but also allows for greater disk capacity per array shelf.

Fusion-io commissioned Tolly to evaluate the performance of its ioControl Hybrid storage approach against a similarly-equipped conventional NVRAM +SSD+Disk hybrid solution. Tolly found the Fusion-io solution to offer high-performance and scalability. In block level access tests, Fusion-io provided up to 700% better performance than the conventional NVRAM+SSD+Disk solution under test. See Figure 1.

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THE BOTTOM LINE

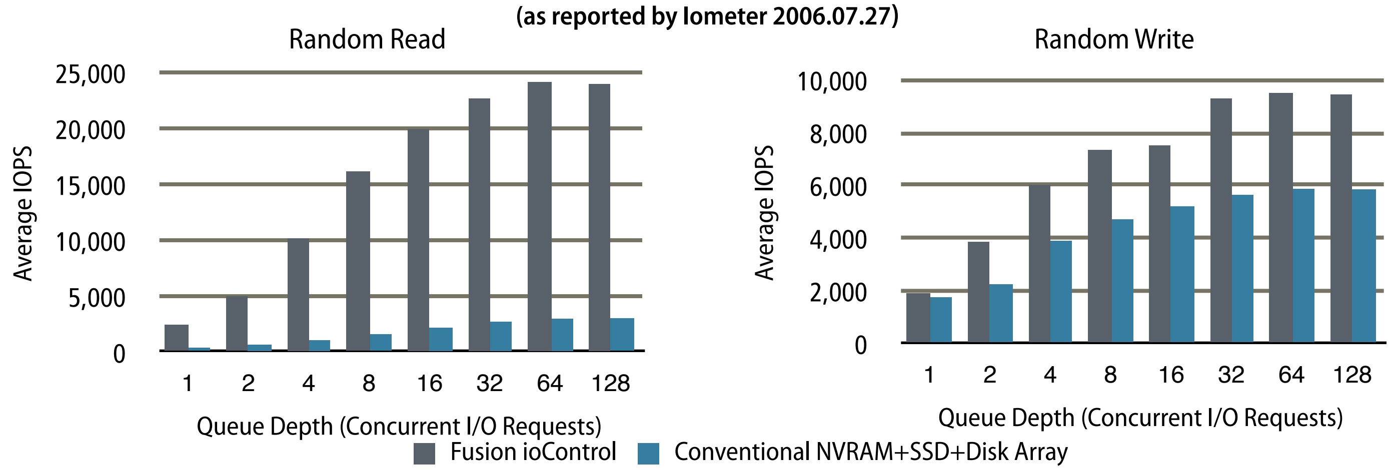
The Fusion ioControl n5 Hybrid Storage Architecture:

1. Provides, on average, 160% higher virtual machine (VM) density, with 60% less latency than conventional arrays
2. Delivers, on average, 740% more 64K random read IOPS and 53% more 64K random write IOPS
3. Leverages "Active/Active" PCIe architecture to provide high bandwidth to applications
4. Provides in excess of 1500MBps of read throughput to I/O-intensive activities such as virtual desktop infrastructure (VDI) "boot storms"

Fusion ioControl n5 Random Read/Random Write Performance vs. Conventional Array

64KB Block Size, Varying Queue Depth

(as reported by Iometer 2006.07.27)



Notes: 4x 50GB LUNs tested per solution. Queue depth reported is per Logical Unit Number (LUN).

Source: Tolly, October 2013

Figure 1

Executive Summary (Con't...)

Background

Conventional NVRAM+SSD+Disk architecture takes an approach where frequently accessed (or "hot") data is placed in an SSD read cache to allow for faster access. These SSDs are typically attached to the SATA II bus, with a maximum speed of 3Gbps, and each takes the place of a rotational disk drive (HDD) inside the array.

While this provides quick access for the data on the SSD cache, SSDs are typically much smaller in capacity than their HDD counterparts. As more SSDs are added to an array, the overall storage capacity is diminished. Further performance degradation is a result of most storage arrays on the market being "Active/Passive," meaning there is only one active controller at any given time, one being reserved for failover conditions. Therefore, only half of the resources purchased are contributing to overall performance at any given time.

With a hybrid flash PCIe architecture, one does not need to sacrifice overall storage capacity for performance. Instead, hot data is stored on large flash devices, directly connected to the PCIe bus, which runs at nearly 128Gbps, 32 times as fast as the SATA II bus. In the case of the Fusion ioControl, the array is equipped with 2x 785GB Fusion-io ioDrive flash memory devices, one for each of the "Active/Active" controllers, providing further performance gains.

References to "queue depth" throughout the document refers to the number of outstanding I/O requests at a given time. While traditionally a serial process, devices with a flash architecture are able to handle many concurrent requests, with far less latency than a conventional HDD.

Virtualization is one of the areas where queue depth becomes important. When dozens or hundreds of VMs are running from the same storage, overlapping requests becomes an inevitability.

Tolly engineers benchmarked the solutions using the open-source Iometer load generator to benchmark the raw input/output (I/O) capacity of each solution as well as to simulate capacity for supporting large numbers of virtual machines (VMs) in a virtual desktop infrastructure (VDI).

Finally, engineers deployed 200 Microsoft Windows 7 virtual machines to benchmark how each solution would respond to a "boot storm" - where all machines attempt to boot simultaneously.

Read/Write IOPS

In terms of raw I/O transaction throughput, the Fusion-io solution delivered more IOPS than the competing solution for every test scenario.

Furthermore, Fusion-io illustrated dramatically greater scalability. In the "read" test, Fusion-io completed 23,962 IOPS in 64KB blocks compared to 3,017 for the competing solution - over 700% greater throughput. Similarly, in the "write" test, Fusion-io delivered 160% more throughput than the competing solution in 64KB blocks, completing 9,439 IOPS compared to 5,838. See Figure 1.

Simulated VM Density

Tolly engineers built a test load to simulate the requirements of a dense windows-based VM environment. A workload for a single VM is defined as 50 IOPs with 64K block size, with 50% Random/50% Sequential, 50% Read/50% Write.

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ioControl n5

Hybrid Storage Performance versus Conventional Storage Architecture

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Those tests show that Fusion-io is able to support up to 222 VMs at a queue depth of 64, which is 170% more than the competing solution. See Figure 2.

Furthermore, when performing a mixed read workload, Fusion-io delivered over 1500MBps of read throughput, which is nearly 375% more than the competing solution. See Figure 3.

VDI "Boot Storms"

It is not uncommon, after system maintenance or at the beginning of a work week, for all users of a VDI environment to initiate boots simultaneously. This is referred to a "boot storm", and it can place a significant short term load on system resources - especially storage, as all VMs are reading their virtual disks.

Overall, Tolly found that VMs running Fusion-io reached a steady state much faster than the conventional hybrid SSD array. 80 seconds after booting the VMs, over 50% of the Fusion-io VMs had reached an idle state, compared to just 15% for the conventional hybrid array. See Figure 4.

Test Results

Tolly tested performance using 64KB block sizes of the Fusion ioControl versus the conventional NVRAM+SSD+Disk with varying queue depth in three different scenarios: Random read/write, latency and in a customized "VM density" workload.

Block Level Performance

Random Read/Write Performance

Tolly used two Iometer instances to generate traffic for 64KB random read/write scenarios, while varying the queue depth from 1 to 128.

Tolly found that the ioControl n5 was able to consistently handle more (multiple times more in the case of random read scenarios) average IOPS at each queue depth than the NVRAM+SSD+Disk solution under test.

In the case of the random read scenarios, Fusion-io demonstrated up to nearly 24,000 average IOPS with the highest queue depth of 128, compared to just over 3,000 I/O transactions for the conventional NVRAM+SSD+Disk array under test. See Figure 1.

VM Performance

In a more complex workload, one emulating a VDI deployment, engineers configured a "50/50/50/50" test (50% Random/50% Sequential, 50% Read/50% Write), and tested both arrays at varying queue depths.

Using 50 IOPs as a determination for one VM, Tolly found that the Fusion ioControl can handle an average of 163% more VMs than the conventional hybrid array, and up to 250% more VMs at low queue depths.

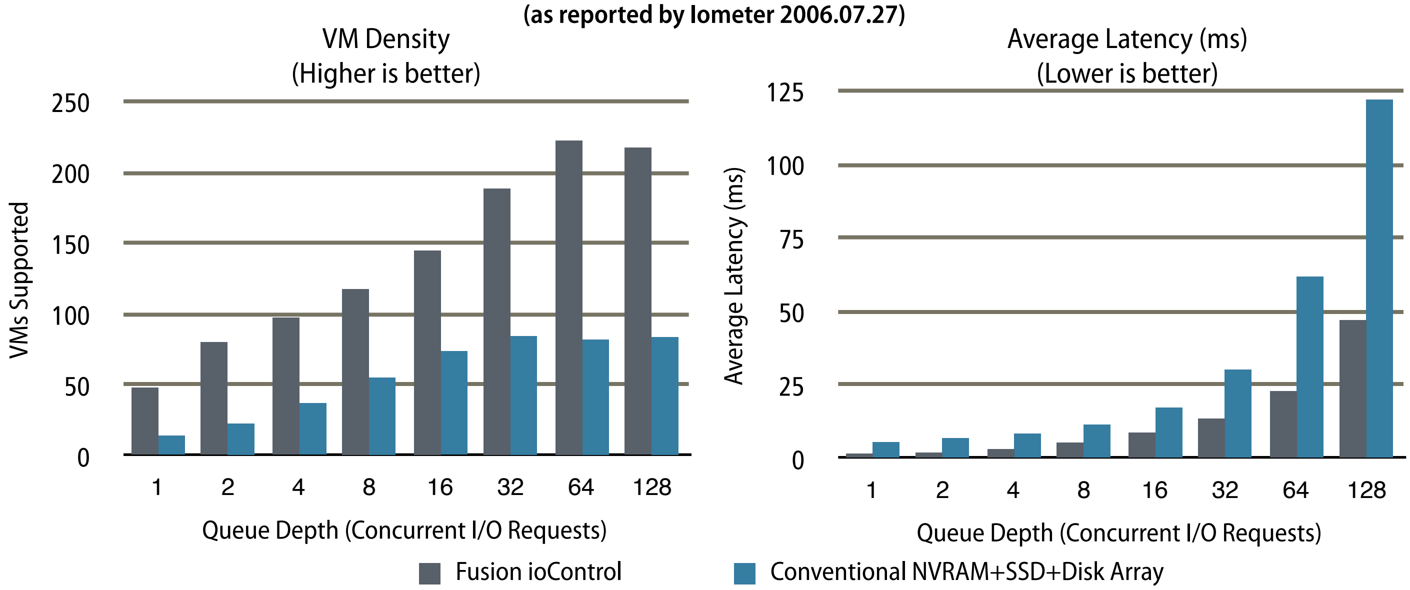
Similarly, Fusion-io demonstrated up to 60% lower average latency than when deployed with a conventional array.

Concurrent Throughput

In a separate analysis, engineers averaged results gathered for random reads and sequential reads, both at 64KB, which is the most common size for VMware workloads, at a queue depth of 64 for each solution.

Tolly found that Fusion-io provides 370% greater aggregate read throughput than the conventional array. This is especially important for VDI applications, as these data access patterns are common for multiple VMs concurrently booting or for activities such as Antivirus scans. See Figure 3.

Fusion ioControl n5 Simulated VM Density and Latency vs. Conventional Array
64KB Block Size, 50/50 Read/Write, 50/50 Random/Sequential, Varying Queue Depth
(as reported by Iometer 2006.07.27)



Note: Results reported by Iometer "50/50/50/50" workload (i.e. 50% Random/50% Sequential, 50% read/ 50% write). Assuming 1 VM requires 50 IOPS. 4x 50GB LUNs tested per solution. Queue depth reported is per Logical Unit Number (LUN).

Source: Tolly, October 2013

Figure 2

VDI "Boot Storm"

In order to simulate the actual performance of each solution in a high-density VDI environment, Tolly engineers provisioned two virtualization hosts, with 100 Windows 7 VMs each, for a total of 200 linked clones per solution.

In a simulated "boot storm," engineers powered on all 200 VMs simultaneously. A script on each VM was configured to run on boot, and report how long the VM required to reach an idle state.

80 seconds into the test, 52% of the VMs running on Fusion-io reported that their boot was complete, compared to only 15% for the NVRAM+SSD+Disk solution. By 100 seconds, 92% of Fusion-io systems had finished, compared to 75% for the conventional array. After 130 seconds, 99% of the Fusion-io systems were finished, whereas the last systems did not complete until 220 seconds into the test on the competing solution. See Figure 4.

Furthermore, after 110 seconds, 98% of the Fusion-io VMs were idle. The competing array did not reach this state until a full minute later. On average, Fusion-io VMs required 89.5 seconds to boot completely, compared to 106.2 seconds for the conventional array.

Test Setup & Methodology

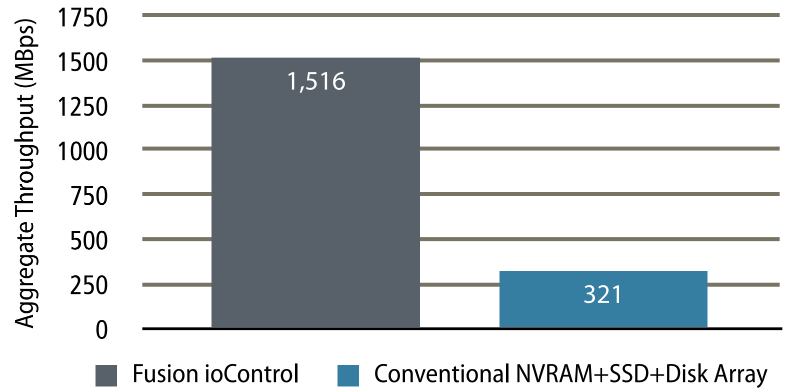
Test Environment

The test bed consisted of one Fusion-io n5-100 hybrid array, equipped with 16x 2TB NL-SAS drives for a total of 22TB of available capacity. Each of the "Active/ Active" storage processors were equipped with a 785GB Fusion ioDrive, and 2x 10GbE

Fusion ioControl Aggregate VM Read Throughput

64KB Block Size, Random Read, Sequential Read

(as reported by Iometer 2006.07.27)



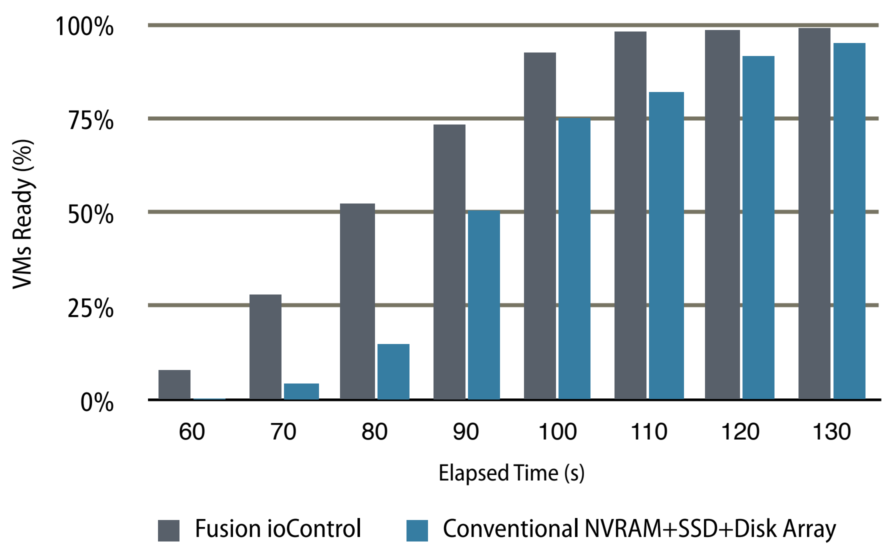
Note: Results reported by Iometer. Average of 64KB Random Write and 64KB Random Read Workloads. 4x 50GB LUNs tested per solution. Queue Depth of 64.

Source: Tolly, October 2013 Figure 3

Fusion ioControl n5 VDI "Boot Storm" VM Ready Time

"Boot Storm" vs. Conventional Array

200 Windows 7 Virtual Machines



Note: Results reported by Tolly AutoIT script. See test methodology for details. Each column indicates what percentage of the total VM pool was "idle" at each time slice. VMs contained on 5 LUNs on each storage system. The conventional array's last VM did not report "ready" until 220 seconds after boot initiated.

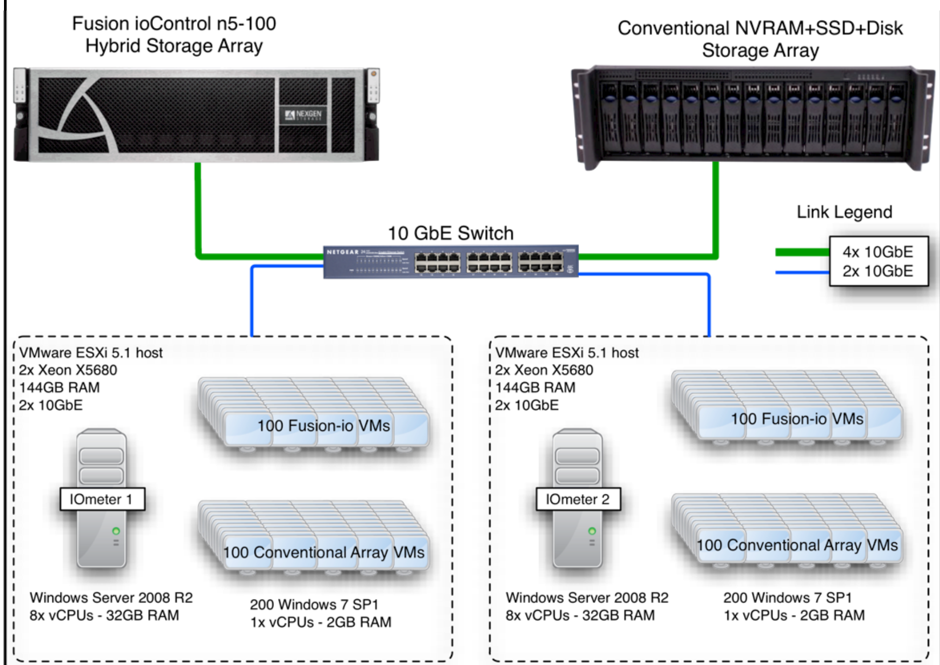
Source: Tolly, October 2013 Figure 4

data ports. The n5-100 was running ioControl version 2.1.1.

The conventional hybrid array was populated with 12x 2TB NL-SAS drives and 4x 300GB SSDs, reporting ~ 15TB usable capacity. Each of the two control modules was equipped with 2x 10GbE data ports, and the controllers were default configured as "Active/Passive". The Fusion ioControl system was equipped with a total of 1.57TB of flash capacity, compared to 1.2TB for the conventional array, and both have power requirements of 550W.

4x 10GbE ports from each array were connected to an IBM RackSwitch G8124 top-of-rack (ToR) 10GbE switch. Two VMware ESXi 5.1 hosts were used to perform testing. Each host was equipped with an HP NC550SFP, dual-port 10GbE NIC, with both ports connected to the 10GbE switch. A vKernel port was configured on each port, and a software iSCSI adapter was configured to load balance all available paths.

Test Bed Topology



Source: Tolly, October 2013

Figure 5

Test Methodology

Iometer

Tolly engineers configured four 50GB LUNs on each of the storage arrays for the Iometer testing. For Fusion-io, two LUNs were provisioned per storage processor.

Two Microsoft Windows Server 2008 R2 virtual machines were provisioned on two identical VMware ESXi 5.1 hosts, each with 2x Xeon X5680 (Hex-core @ 3.33GHz) and 144GB RAM. Each Server 2008 R2 instance was configured with 8 vCPUs and 32GB RAM, using a separate SSD as their boot disks. Two LUNs were mounted on each VM through vSphere.

The test specification consisted of the default set of Iometer workloads, as well as a 64KB "50/50/50/50" test, using a 50% Read/50% Write and 50% Sequential/50% Random access specification. The test was configured to run for two minutes as each interval, and was configured to step through queue depths of 1 - 128 per LUN.

VDI "Boot Storm"

On the same two VMware ESXi 5.1 hosts, engineers provisioned a set of 200 Microsoft Windows 7 SP1 clients for each solution, configured with 1 vCPU and 2GB RAM. A total of 6 LUNs were created on each storage array. One LUN held the golden image, from which all others were cloned. The other 5 LUNs contained the boot disk for 40 VMs.

The Windows 7 instance was according to VMware best practices, and were configured to auto-login. Engineers used an AutoIT v3 script which would launch as soon as the user signed in, and poll the system CPU until it reached an idle state (< 10% CPU) for 10 consecutive seconds The script would then capture the elapsed time, and write it to a network share for analysis. The network share was mounted only after the timing script had completed.

The test was run three times, with the third run's results reported. The first two runs were meant to allow both solutions to cache the VM data at the highest possible tier prior to the production run. To start the test, all 200 VMs across both hosts were selected in vSphere and powered on simultaneously.

About Tolly

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About Fusion-io

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