Performance Benchmark of the SGI TP9400 RAID Storage Array

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Abstract:

This paper will discuss our experience with the performance of SGI's TP9400 RAID Storage Array. Using the standard SGI diskperf performance testing utility and a locally written benchmark, we will demonstrate what actual performance improvements that can be expected over locally connected XFS scsi filesystems. We benchmarked the TP9400 using a shared connection via a Brocade switch between a desk-side Origin 2000 and an Onyx system. This paper will present our findings of the thoughput for each SGI system using dedicated partitions and a CXFS shared filesystem.

Methodology

There are many ways to configure a filesystem. We learned, the hard way, that a configuration that works well on one platform or application, does not necessarily provide the same performance in all situations. This paper is an account of our experiences as we transition from an Origin 2000 with scsi attached storage, to a fiber channel attached TP9400 storage array and a new 64 processor Origin 3800.

To test our configuration, we used the standard SGI benchmark, diskperf(1) and a locally written tool. The diskperf utility does a very complete test of various types of I/O and it is provided in the standard IRIX distribution. As a cross check, our locally written tool called diskrate, benchmarks very simple sequential forward write and reads.

Diskrate Methodology

```
fd = open(streamName, "w" );
for ( block = 0; block < Nblocks; block++ ) {
    n = write( fd, Buffer, BlockSize );
}
```

Sample Output

```
## diskrate ## blocksize=262144 filesize=3000
BlockSize = 262144, 11444 Blocks  --> 2999.976 MB
1 passes writing 1 times then reading 5 times
1 files, with cache flushed before reading.
/big/i/perf/ppwmj1/testfile_5812534
Writing for 240.66 sec @ rate of 12.465619 MB/sec with cpu of 35.17/0.05 sec
Reading for 98.91 sec @ rate of 30.330360 MB/sec with cpu of 23.75/0.05 sec
Reading for 71.74 sec @ rate of 41.817340 MB/sec with cpu of 21.65/0.04 sec
Reading for 74.95 sec @ rate of 40.026363 MB/sec with cpu of 21.93/0.04 sec
Reading for 78.94 sec @ rate of 38.003242 MB/sec with cpu of 22.86/0.04 sec
Reading for 79.20 sec @ rate of 37.878484 MB/sec with cpu of 23.83/0.05 sec
Unlink  for 1.48 sec with cpu of 1.21/0.00 sec

# diskperf -D -W -c 10m fred
#---------------------------------------------------------
# Disk Performance Test Results Generated By Diskperf V1.2
#
# Test name     : Unspecified
# Test date     : Tue Apr 10 08:08:57 2001
# Test machine  : IRIX64 origin 6.5 07201611 IP27
# Test type     : XFS data subvolume
# Test path     : fred
# Request sizes : min=16384 max=4194304
# Parameters    : direct=1 time=10 scale=1.000 delay=0.000
# XFS file size : 12582912 bytes
#---------------------------------------------------------
# req_size  fwd_wt  fwd_rd  bwd_wt  bwd_rd  rnd_wt  rnd_rd
#  (bytes)  (MB/s)  (MB/s)  (MB/s)  (MB/s)  (MB/s)  (MB/s)
#---------------------------------------------------------
      16384    0.93    8.52    0.81    1.94    0.74    1.80
      32768    1.39   11.62    1.20    3.13    1.11    3.18
      65536    2.55   14.24    2.21    4.59    2.14    5.01
     131072    4.46   15.45    3.97    7.56    3.68    7.71
     262144    8.40   18.28    8.59   12.29    8.23   12.48
     524288   15.82   23.21   12.24   18.25   11.44   19.38
    1048576   17.92   30.75   16.25   27.17   15.78   26.24
    2097152   23.28   34.29   19.06   32.67   21.85   31.80
    4194304   27.79   37.06   25.44   36.04   26.83   34.84
```

Our Humble Origin

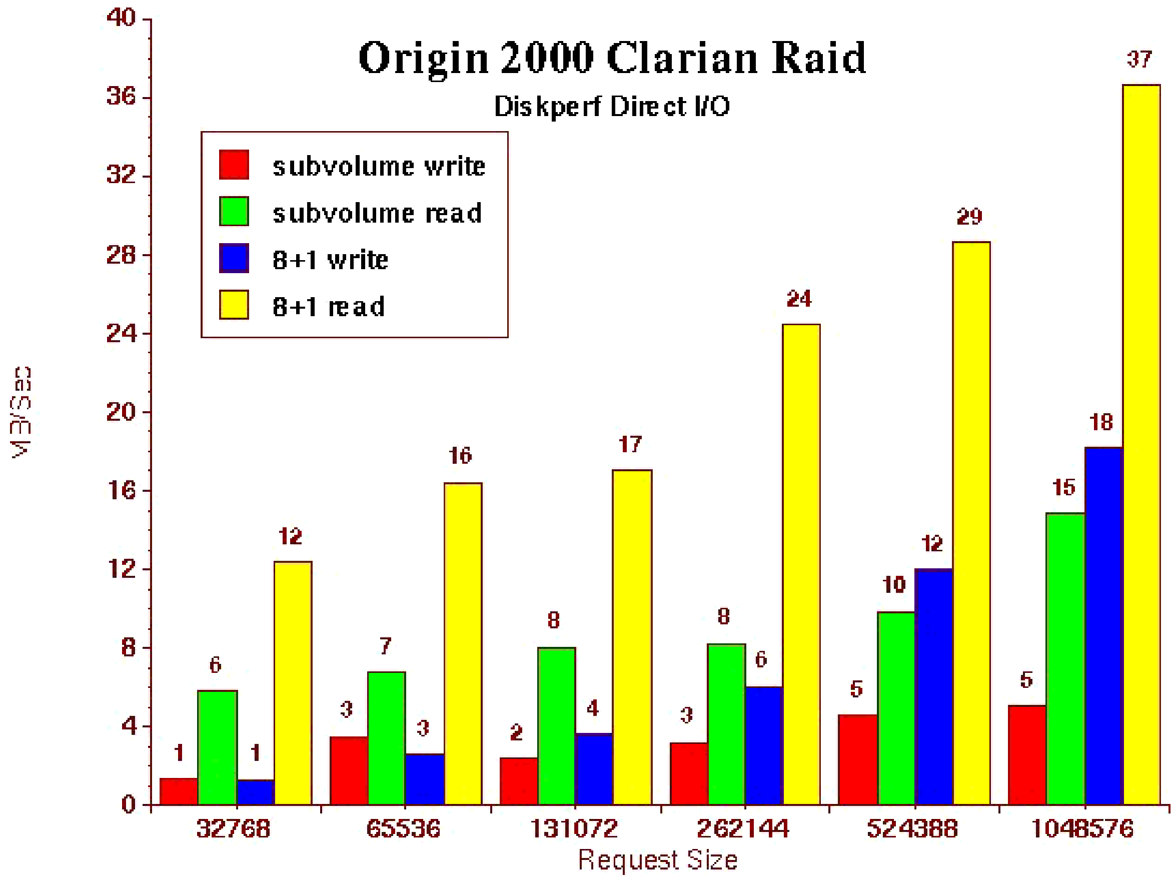
Before I begin describing our performance experience with the TP9400 RAID storage array, we need to look, for comparison, at our humble Origin. Tuning our SGI I/O performance has been a journey, with with many lessions learned along the way. And this journey began with the analysis of our modest 8 CPU Origin 2000.

The application mix on the Origin 2000 is primarily CPU bound MPI finite analysis codes. These programs, when they did perform any I/O, were predominatly write only. For this reason, performance of the I/O sub-system was not a primary concern and not part of the acceptance criteria for production. However, when we did benchmark the performance, it was alarming and in need of some serious attention.

The Home and scratch filesystems were configured on a scsi attached clairian RAID storage device as an xlv. Initially, they were setup with a stripe across two sub-partitioned LUNS. Each of the LUNS were built as an raid3 8+1. This configuration is simular to how the filesystems on another, non sgi system, were built. Previous experience had shown this provided acceptable performance.

After the system was put into production, a benchmark was performed. It showed we had amazingly poor I/O performance! This gave us two a very important lessons. First, we learned that one should always benchmark the performance of your I/O sub-systems. Prior experience was of little benifit. Second, we learned it is best not to sub-partition your LUNS. We found a serious performance degradation if you use these sub-partitions in a stripe. Each write had to be syncronised across all 16 spindles on the two raid3 8+1 arrays.

A "before and after" diskperf benchmark demonstrates this degradation. The following graph shows that at a 1meg request block size, we were getting 5 MB/second on writes and 15 MB/second reads. It is more common for our applications to use a 65,536 request size. At this request size, the direct writes were barely 3 MB/second! This came as quite a surprise, and was clearly not acceptable. So, we reconfigured the filesystems to use a clean 8+1 lun. By eliminating the subvolume partitions, and the two lun stripe, the performance of the filesystems improved by more than double.



Evaluation of the TP9400

A new computing requirement gave us the opportunity to upgrade our Origin service from an 8 CPU Origin 2000, to a 64 processor Origin 3800. On the new Origin 3800, we decided to use the TP9400 storage array device. This new workload had a potential for a significantly intensive I/O traffic. Learning from our previous experience, we setup a project to benchmark and evalulate the I/O performance of the TP9400 storage array. We also made this a part of our acceptance criteria for the new system.

In preparation for the benchmark, SGI provided us with a loaner Origin deskside, a brocade switch, a TP9400 with a controller enclosure and one 73 GB disk enclosure. The controller was configured with 2 front end minihubs (gbics) and 4 backend minihubs, The datacenter installed an Onyx 2 system in order to perform the shared filesystem testing. Our test plan consisted of the following steps.

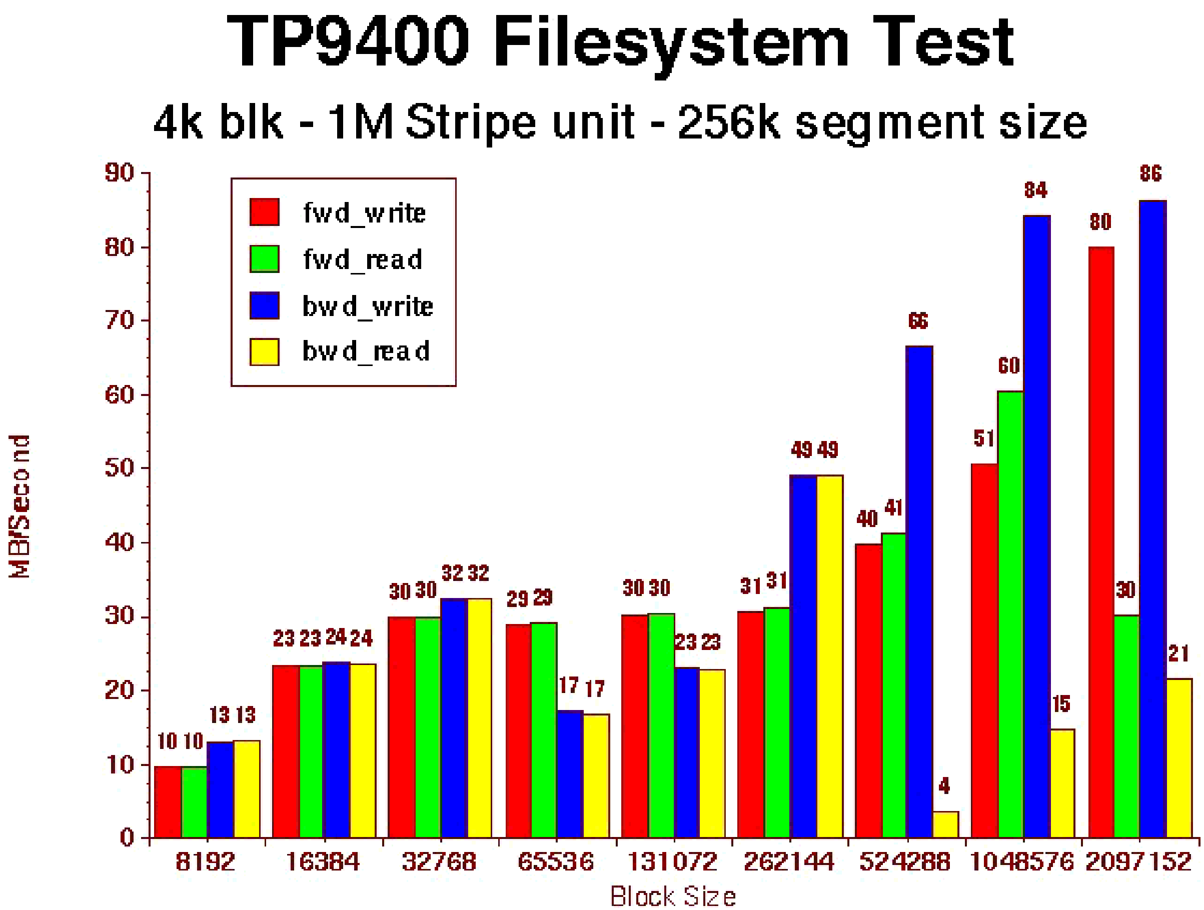
- Install test software on Origin and Onyx 2
- Collect PCP pmlogger data to validate benchmark outputs
- Direct attach the TP9400 to the Origin
- Make a dedicated 4+1 XFS filesystem with a 2 lun stripe
- Run the test script
- Direct attach to the Onyx 2
- Run the test script
- Connect the TP9400, Origin and Onyx to the Brocade switch
- Remake the filesystem as a CXFS
- Run the test script standalone on the Origin
- Run a standalone test on the Onyx 2
- Run the test simutainiously on the Origin and the Onyx 2

A learning experience

Learning how to configure the TP9400 was at first fairly difficult. We found the man pages for the various tools like xvm, cmgr, and the online help files for tpssm7 not well integrated and didn't provide an overall picture. But after some study, and some help from SGI, we managed to configure dedicated and shared cxfs filesystems. Essentually, we used the default settings in tpssm7 and xvm.

Dedicated Filesystem Test

Our initial benchmarks found simular results from both the Origin deskside and Onyx2 systems. The PCP performance data matched very well the output results from each of our benchmarks. Also, we found no difference in performance when the TP9400 was direct attached or connected via the Brocade switch. Finally, each system's benchmarks performed on the CXFS shared filesystem were also consistant with all the previous tests. The CXFS filesystem added no degradation to the filesystem performance. A summary of these benchmarks are displayed in the following chart.

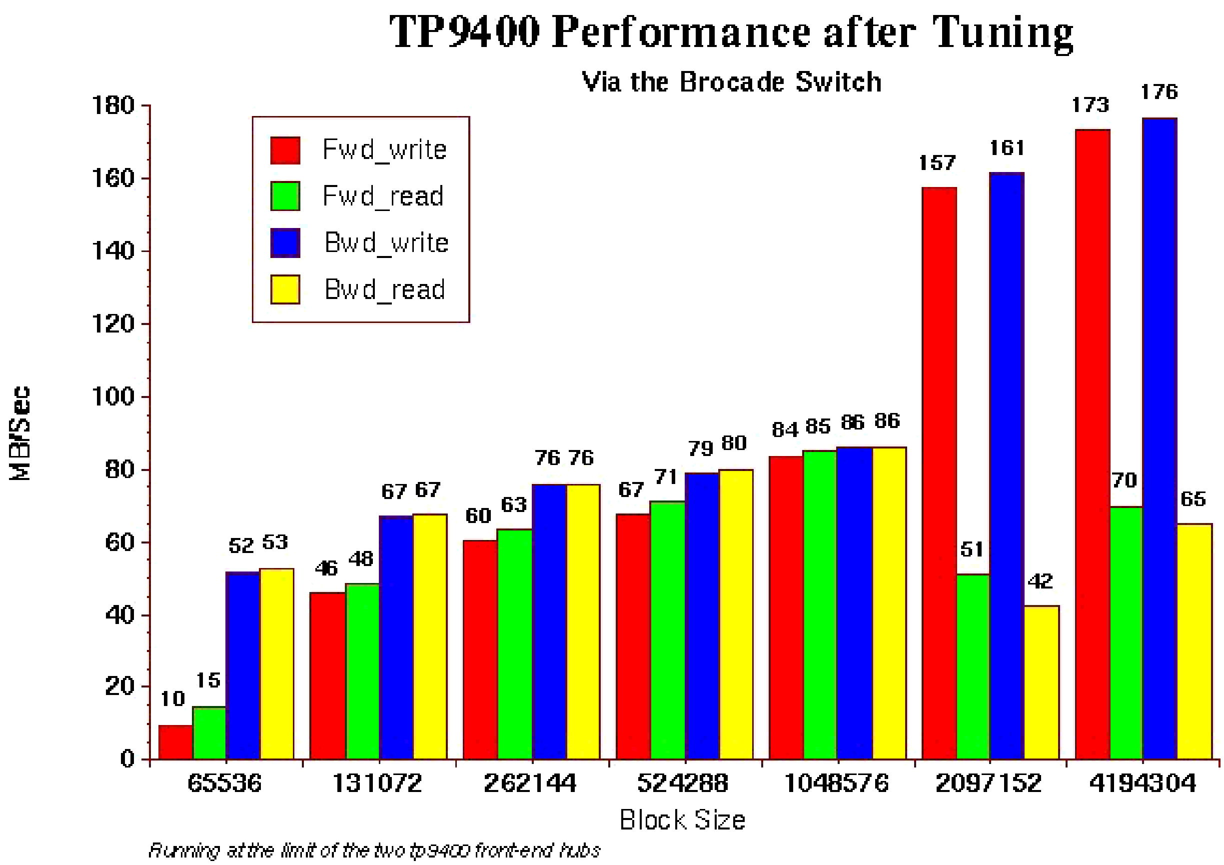


Benchmark evaluation

The results were considerably better than the benchmarks performed on our humble Origin 2000. But they were still consistantly lower than our expectations. Each Gbic mini-hub should be able to sustain a maximum of 100MB per second. Striping across the two 4+1 LUNS, we expected the transfer rates to be some what less than 200MB per second. However, the maximum observed thoughput was less than half that rate! Running simutainious tests on both systems provided the same maximum performance of around 80 MB per second. Also, running multiple streams on the same system resulted in a rate linear to 80 MB/Sec divided by the number of streams. Clearly, we were missing something in our configuration.

A new concept to us in working with the TP9400 is the fact that there are multiple paths through the HBA controllers to the TP9400 controllers. Unless you configure it, the system will choose it's own primary path. After some digging, we found that the system choose the same primary paths for each of our LUNS routing all the I/O through a single minihub. The *scsifo -d* command displays these default paths. To improve benchmarks, we took the following actions.

- Enabled Command Tag Queueing with xvm
- Setup the primary paths by configuring a failover.conf
- Rebuilt the filesystem with a 65536 block size
- Increased the stripe size to 2048 Meg

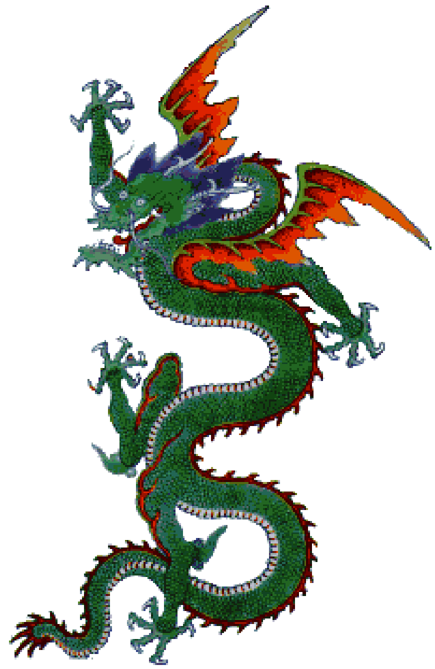


Results after Tuning

As you can see from the above graph, the performance throughput considerably improved. The performance co-pilot displays showed that the I/O was evenly distributed via two HBA channels and the transfer rates where running at the limit one would expect; limited by the bandwidth of the two front end Gbic hubs. The drop in the read performance is explained by the fact we did not enable the read ahead cache. Enabling the read ahead cache can improve performance, but since our application workmix is very write intensive, we decided to configure the TP9400 cache to 80% write and 20% read and not enable the read ahead cache in order to give preference to the write operations. We are still evaluating this decision, and once more is known about the potential application workmix on the new 3800 platform, the cache ratios will be adjusted and a we will make a final decision about enabling the read ahead cache.

It is also interesting to note that the knee in the performance that occurs at the stripe size boundry. This emphasizes the importance that of choosing a block size and stripe size that matches the characteristics of your applications.

There be dragons here



In the process of our stress testing, we discovered a serious problem. The system became unresponsive when we ran 10 streams writing to 6 Gigabyte files. The problem was reported to SGI (case number 2174429).

The problem occurs with any program performing very large I/O to the TP9400 on either a cxfs or a local lxvm. It does not occur on the local jbod scsi disks. We were able to reproduce the problem with any program that performs any significant I/O, like diskperf or dd. As soon as the buffer cache is flooded, programs running before the test will continue to run, but appear to hang on exit. Once this occurs, the I/O throughput drops to less than 2MB per second. If you are lucky enough to have a session open, you have one chance to perform a killall on the programs performing the I/O. If left alone, the system will eventually recover. On our test system, one recovery took 6 hours to complete.

Sgi believes the problem is caused by something called the Macisort routine. This routine sorts I/O operations to minimize disk head thrashing. The I/O requests are performed not on the order of the requests but according to the physical layout of the drive sectors. Apparently, the kernel was spending 100% of it's resources sorting the kernel buffer cache. Sgi provided us with a way of turning off the Macisort. However, this did not fix the problem. After further analysis, sgi identified the problem as bug number 817044 and is fixed in patch number 4230. This patch requires some systune parameters.

xfs_dcount:

> This parameter was introduced in a patch for CXFS. It controls how many xfsd threads to start. When this parameter is set to 0, the default, the system will allocate 4 xfsds plus one xfsd for every 32768 pages, after the first 32768 pages of physical memory; up to the maximum of 13. The forumula is:
> xfs_dcount=(memory_size*1024*1024-page_size*32768)/(32768 * page_size)
>
> If you choose the non-default scaling, the maximum number of threads is 64. The xfsd threads deamon does the disk block allocation for delayed allocation buffers. These buffers have their space reserved when written to, but the actual selection of disk blocks is delayed until a fsync(2) of the file or the buffer ages long enough for bdflush to push it out to disk.

xfs_dcontention:

> When non-zero, xfsd keeps track of what inodes it is working on, and will avoid picking a buffer belonging to an inode that another xfsd is working on.

News of this patch came to us just 12 hours before our Origin 3800 was due to be put into production. Unfortunatly, the degradation still occurs, even with xfs_dcontention set to a non-zero value, so the problem remains under investigation.

Summary and Conclusions

The most important advice that I can give is that, on every I/O reconfiguration; take the time to test your I/O performance. *You may be very surprised what you find!* The standard IRIX distibution contains a standard tool called *diskperf* that does a very complete I/O performance analysis benchmark. This utility is very simple to use. For example, to perform a 3GB benchmark on the current filesystem:

/usr/sbin/diskperf -D -W -c3g testfile .

Sgi suggested that we enable Command Tag Queuing (CTQ). When enabled, the drive will setup a queue for I/O requests. The CTQ is enabled in in fx with the command: **fx> label/set/parameters**. Press enter until you see *Enable CTQ*. Fx will then ask you to enter the queue depth. This queue depth is calculated by the following forumula.

$$\frac{256 - (\text{LUNS} * \text{hosts})}{\text{LUNS} + \text{hosts}}$$

When you build your filesystems, try to involve as many spindles as possible. And for the best performance, never sub-partition your LUNS. We learned this lession the hard way when we initially configured the Origin 2000 system.

The maximum rated performance of the TP9400 is approximatly 250 MB/second write, and 350 MB/second read. The TP9400 can have up to 4 host interfaces called front end hubs. Each of these interfaces have a performance limit of approximatly 100 MB/second. A very high performance filesystem can be built by striping across 4 LUNS, each configured as raid3 4+1. By setting your default primary paths, with the /etc/failover.conf, to evenly distribute the I/O over all 4 host bus adapter (HBA) controllers, the maximum throughput can be achieved.

At the time of our benchmark, the TP9400 was configured with only two host interfaces. Also, the drives ordered were the high capacity 36GB disks. Binding a filesystem described above would make a filesystem too large for our needs, and not fit our service requirements. Performance probably would have been better if we had configured the TP9400 with the smaller 18GB drives. But this is a case there where we had to balance service definition requirements against configuring the system for maximum performance.