

How to achieve over 2 TB/hour network backup with Integrity entry-class servers running HP-UX 11i v3

Technical white paper

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Introduction

Network backup (also known as remote backup) is widely used today in environments where servers with anywhere from a few megabytes to tens of gigabytes of data need backup and recovery, but the cost of direct connection to a SAN is not justified. Network-based backup has become feasible for servers with larger volumes of data attached, primarily because of advancements in network speed and performance. The slower (10/100bT) network speeds available in the late 1990s contributed to making network-based backup impractical for servers with data volumes exceeding tens of megabytes. In those days backup of one terabyte of data per hour was possible only on very large servers having 20 or more locally-connected tape devices.

With the introduction of 1-gigabit (1-GbE) and 10-gigabit (10-GbE) Ethernet network adaptors, servers with backup data volumes exceeding tens of gigabytes are now practical candidates for network-based backup strategies. This advancement in network technology, coupled with faster tape devices, virtual tape libraries, and faster servers with greater overall I/O throughput, enables integration and deployment of small-footprint backup servers capable of backing up 1 to 2 terabytes of network-delivered client data per hour.

This white paper documents how HP configured standard equipped HP Integrity rx3600 and rx6600 entry-class servers running HP-UX 11i v3 to deliver superior network backup services, easily achieving backup performance in the two terabyte per hour range. This white paper discusses the best practices for configuring and enabling these servers to perform at such a high level.

Objectives

HP strove to characterize the backup and restore performance of entry-class Integrity servers (primarily, the rx3600 and rx6600 servers) running HP-UX 11i v3 and using the HP Data Protector utility. Using technologies that are most commonly deployed in data centers today, HP performed this characterization using 1-gigabit Ethernet (1GbE) and 4-gigabit Fibre Channel (4Gb FC) adapters.

The “Best practices” section of this whitepaper documents how the network backup server, operating system (OS), and backup utility are tuned for maximum backup and restore efficiency. No specific recommendations are provided for tuning the client systems, as these systems should be tuned optimally for their primary application services.

Testing methodology

The testing methodology used for this performance characterization and tuning effort is much like what would be done for analysis of any backup server environment. This methodology can be used as an example to pattern similar backup characterization and performance testing and tuning.

The first step is to understand the configuration of the backup environment involved. To acquire this understanding, HP recommends devising a topology drawing that shows the backup server, clients, data storage, backup devices, and the interconnections within the LAN and SAN.

Once the environment topology is known, the next step is to identify potential throughput limitations in the configuration and to do stress and limits testing to discover the maximum throughput achievable at each point. For example, in Figure 1 the key throughput bottlenecks to stress and characterize are the 1GbE connections between the clients and backup server, the LTO-4 tape device throughput, and the 4Gb FC port throughput. In addition, to obtain optimal performance, the Data Protector backup utility should be tuned appropriately for the environment.

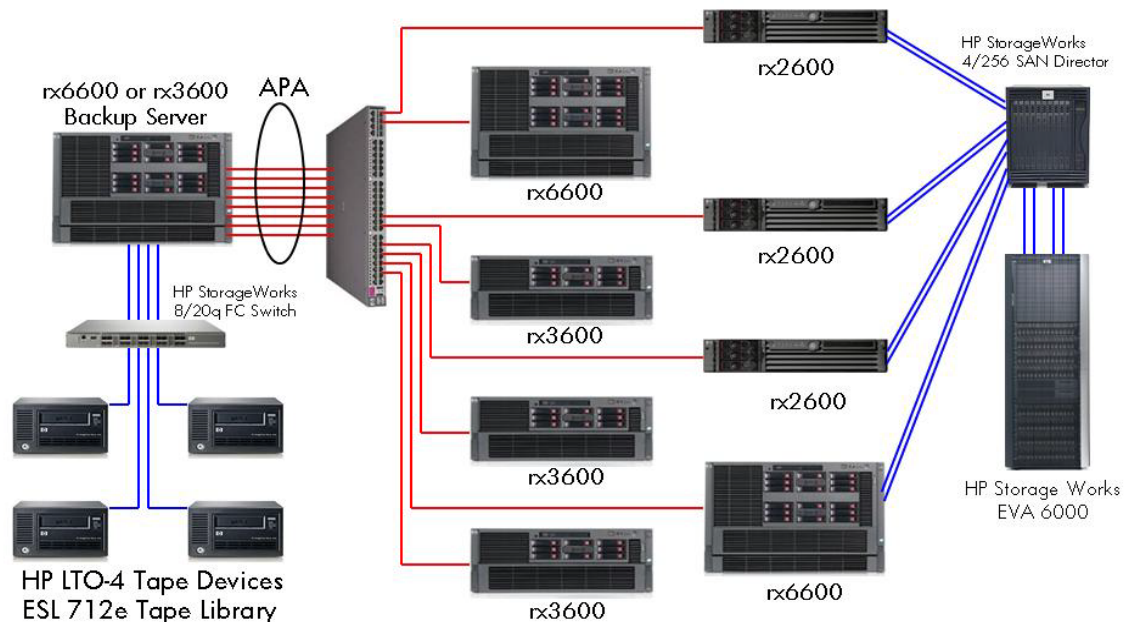
Detailed information about the tests performed to characterize each of the potential throughput limitations and to optimize performance is provided later in the “Identifying solution limits, stress points, and optimal tuning” section. Overall results of the backup server characterization tests are summarized in the “Summary of test results” section at the end of this paper.

To optimize backup and recovery operations, perform similar limit and stress point characterizations with each customer’s specific backup server environment. This paper does not cover all the possible backup tuning and configuration optimizations available. It does cover optimizations that are most common and easiest to leverage to any production network backup server environment.

Test environment configuration

The base configuration and test environment used for this backup server characterization effort is a single backup server with eight client systems providing the backup/restore data. The clients are a mix of Integrity entry-class servers — rx2600, rx3600, and rx6600 — all running HP-UX 11i v3 Update 4 (Fusion 0903). Data backup and restore operations for this characterization were performed over a private 1GbE network. Each of the eight client systems uses a single 1GbE NIC port connected to the private network for transfer of backup/restore data to the backup server. The backup server has eight 1GbE NIC ports aggregated using Auto Port Aggregation (APA) to provide a single backup server target network IP address. Figure 1 gives a high-level view of the test environment configuration and connectivity. The private 1GbE Ethernet network connections are shown in red, while the FC SAN connections are shown in blue.

Figure 1: Test environment configuration



Backup server configuration

Both entry-class Integrity rx3600 and rx6600 servers running HP-UX 11i v3 Update 4 (Fusion 0903) were used as backup servers for this performance characterization effort. Additional configuration details for the two server models are:

rx3600 / HP-UX 11i v3 backup server

- PCI-Express backplane option
- Two Dual-core Intel® Itanium® 9140M processors
- 16 GB DDR2 memory
- Two PCI-e dual port 4Gb FC HBAs (P/N AD300A)
- Two PCI-X quad port 1GbE NICs (P/N AB545A)

rx6600 / HP-UX 11i v3 backup server

- PCI-Express backplane option
- Four Dual-core Intel® Itanium® 9140N processors
- 32 GB DDR2 memory
- Two PCI-X dual port 4Gb FC HBAs (P/N AB379B)
- Two PCI-e quad port 1GbE (1000Base-T) NICs (P/N AD339A)

Client system configurations

Any system platform and OS that the backup utility supports as a client for network-based backup could have been used for this backup server characterization effort. For example, HP Data Protector supports HP-UX, Windows, Solaris, AIX, Linux, and many others as clients. HP Integrity servers running HP-UX were chosen as the clients because these servers are prevalent worldwide in customer data centers that host mission-critical applications and services.

The eight client systems used for network backup to the backup server included rx2600, rx3600, and rx6600 Integrity servers of varying memory and processor configurations:

- rx2600, two processors, 2 GB memory
- rx2600, two processors, 4 GB memory
- rx3600, two dual core (4 CPUs), 8 GB memory
- rx6600, one dual core (2 CPUs), 4 GB memory

Each client used a single dedicated 1GbE port to connect to the private network used for transferring backup/restore data between the client and the backup server.

To determine whether noticeable differences occur when data is stored on either internal SAS disks or externally-connected SAN storage, data for each client was stored on either SAS or SAN interconnect. To enable configuration of four separate data streams in the backup utility, backup data was kept in four separate file systems with separate file-system mount points on the client systems.

The mix of backup data types does affect the throughput and performance of tape devices that compress data written to tape media. The more compressible the data being written to tape, the higher the overall data throughput. Binary executables are not nearly as compressible as structured data files. Client backup data used for this test included both binary executables and structured data files, with the typical backup data mix of 15 to 20% binary and the rest being structured data in the form of record formatted files and database tablespace files.

Additional test environment configuration details

Additional components used in the test configuration shown in Figure 1 are:

- HP StorageWorks Enterprise Systems Library (ESL) 712 E-series tape library
- HP StorageWorks LTO-4 Ultrium 1840 FC tape devices (installed in the ESL 712e tape library)
- HP StorageWorks 6000 Enterprise Virtual Array (EVA6000) Storage Subsystem
- HP StorageWorks 4/256 Director FC Switch
- HP StorageWorks 8/20q FC Switch
- HP ProCurve Switch 3400cl with 10/100/1000-T port modules
- HP-UX 11i v3 Update 4 (0903 Fusion) Data Center Operating Environment (DC-OE)
- HP Data Protector version 6.1
- Online JFS is available as an add-on license for the Base Operating Environment (BOE) and is bundled with all the other HP-UX Operating Environments

Identifying solution limits, stress points, and optimal tuning

One of the first steps of performance characterization is to identify the limits and stress points of the environment. Characterization of the backup server requires knowledge of the maximum throughput achievable at the 1GbE NIC ports, the 4Gb FC HBA ports, and the LTO-4 tape drives during a backup. Knowledge of these throughput limits helps enable optimal configuration of the overall backup operation.

Optimal configuration also depends on optimal settings for the backup utility tunables. The HP Data Protector backup utility supports numerous tuning features, including adjustment of I/O block size and the number of buffers to use for writing to backup devices. Data Protector, as with other backup utilities, uses default settings of 8 I/O buffers and 64KB I/O blocks. While running tests to identify the bandwidth limits of the network 1GbE ports, the 4Gb FC ports, and the I/O throughput of the LTO-4 tape devices, the following combinations of backup utility tuning parameters were used:

- 8 buffers and 64KB I/O blocks
- 16 buffers and 128KB I/O blocks
- 16 buffers and 256KB I/O blocks
- 32 buffers and 128KB I/O blocks
- 32 buffers and 256KB I/O blocks

Note

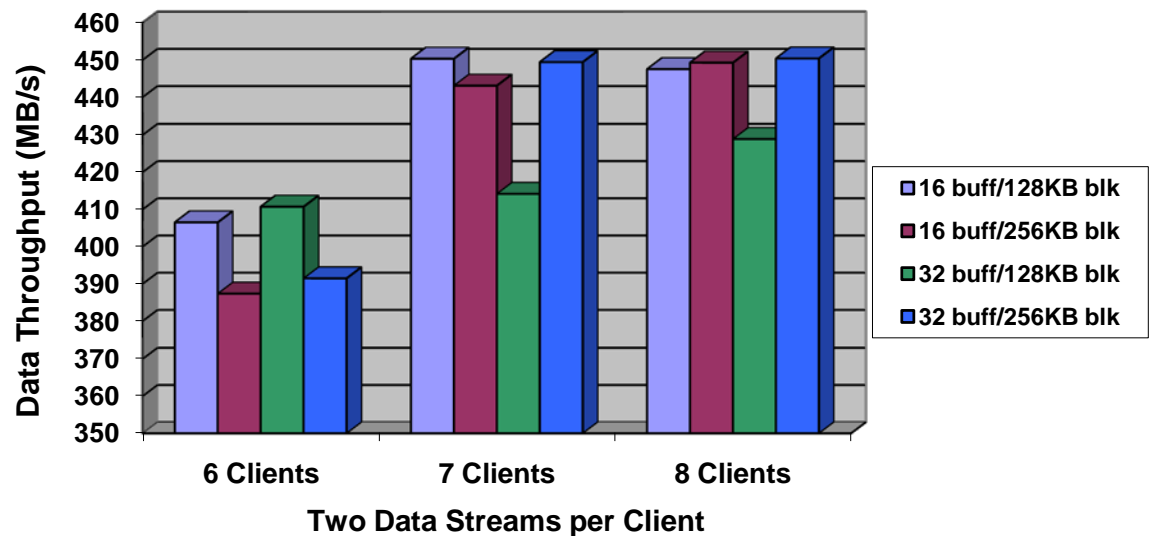
The backup and restore tests performed for this performance characterization were run at full speed. The tests did not employ network throttling nor other means of limiting the backup/restore data traffic on the network or the throughput performance on the backup server or client systems. Use of network bandwidth capping features available with Data Protector and most major backup utilities may be desirable in data centers that cannot deploy a separate backup network and so must transmit backup/restore data over a primary, shared network.

Backup utility tuning testing

To identify the optimal combination of backup utility tuning parameters for the number of I/O buffers and the size of I/O blocks, HP used two data streams from an increasing number of clients. The backup data streams were distributed equally across two tape devices. HP used only two data streams per client so that the 1GbE port limit for each client would not affect the results. HP used two tape devices so as to assess the scale-out factor of the backup utility for this tuning analysis.

Overall testing found that the most optimal tuning combination for this particular backup server configuration was 32 buffers and 256KB I/O blocks. Figure 2 shows that two HP LTO-4 tape devices given the data mix used for this test effort can back up 450 MB/s total, or an average of 225 MB/s per LTO-4 tape device.

Figure 2: Backup utility tuning settings for number of I/O buffers and size of blocks



The 256KB I/O block size for the backup utility tunable is ideal for systems running the Online JFS product. With Online JFS and no additional file-system tuning, this larger I/O block size implicitly enables the Online JFS Direct I/O feature for file reads. The feature can also be tuned using the `vxtunefs` command to set the JFS (VxFS) file-system tunable `discovered_direct_iosz`, which is available with VxFS v4.1 and newer versions. With Online JFS, Direct I/O is enabled implicitly if the read or write size is greater than or equal to the value set for the `discovered_direct_iosz` tunable. The default value for `discovered_direct_iosz` is 256 KB.

With Direct I/O enabled, read data goes directly to the user buffer and bypasses the file buffer cache of the operating system. This avoids a memory copy of file data between buffers and reduces CPU utilization, thereby increasing overall backup performance.

For information about additional file system tuning capabilities available on client systems, see the "JFS Tuning and Performance" white paper available at:

<http://www.hp.com/go/hpux-core-docs>
(click on the HP-UX 11i v3 product link)

The following subsections describe stress test results for the 1GbE port and the LTO-4 throughput limits. To demonstrate how backup utility tuning can affect overall throughput, the tests use the backup utility tuning combinations of 8 buffers/64KB blocks and 32 buffers/256KB blocks.

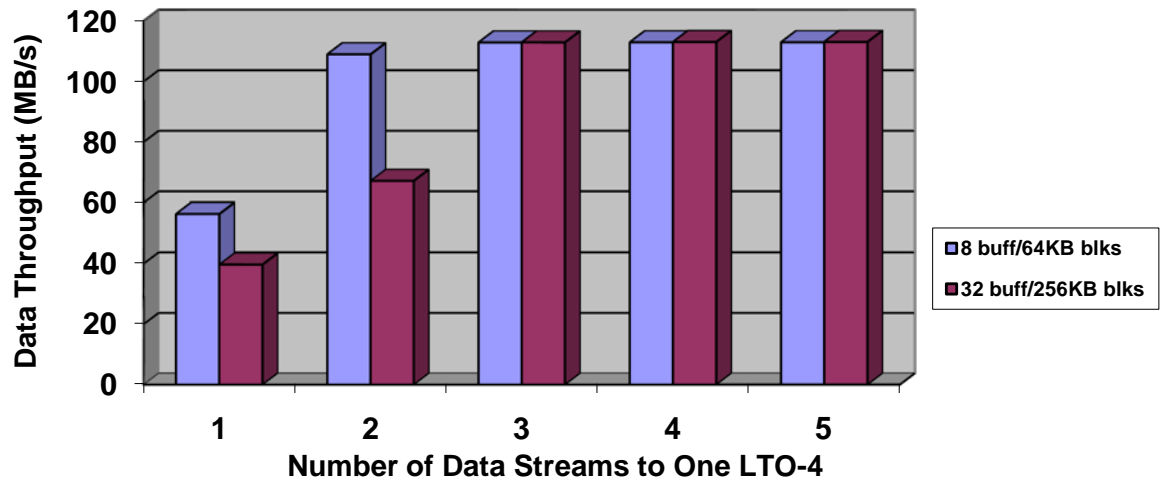
Note

Because this network backup server characterization analyzes data storage I/O throughput instead of network bandwidth, data rates are measured and reported in bytes (B) rather than bits (b).

One-gigabit Ether port limit testing

To determine the maximum backup data I/O throughput that can be expected for each client over a single 1GbE NIC port, multiple backup cycles were performed, increasing the number of parallel backup data streams and, for each cycle, rerunning the tests with different backup utility tunable settings for the number of buffers and block size: first with 8 buffers and 64KB blocks, and then with 32 buffers and 256KB blocks. Figure 3 shows the results of these tests.

Figure 3: Results of 1GbE port backup throughput stress tests



As shown, the tests demonstrate that the maximum data I/O rate for a single client using a single 1GbE port is about 113 MB/s, which is also the maximum link speed for a 1GbE port. Tests show this throughput rate can be achieved with three concurrent data streams on the client; however, four parallel data streams were used from each client in subsequent tests to make allowances for temporary lags in any individual data stream resulting from small files, disk agent delays, and so forth. Four data streams better assure consistent maximum client data-transfer rates to the backup server.

These tests demonstrate that for one or two data streams per client, the optimal backup utility tuning setting for data throughput over the 1GbE NIC port is the tuning combination of 8 buffers and 64KB I/O blocks. For three or more data streams, both tuning combinations perform equally. However, the tests for determining optimal tape drive throughput (described in the “HP StorageWorks Ultrium 1840 LTO-4 limit testing” section) reveal that the tuning combination of 32 buffers and 256KB IO blocks is more optimal for overall throughput to the LTO-4 tape devices.

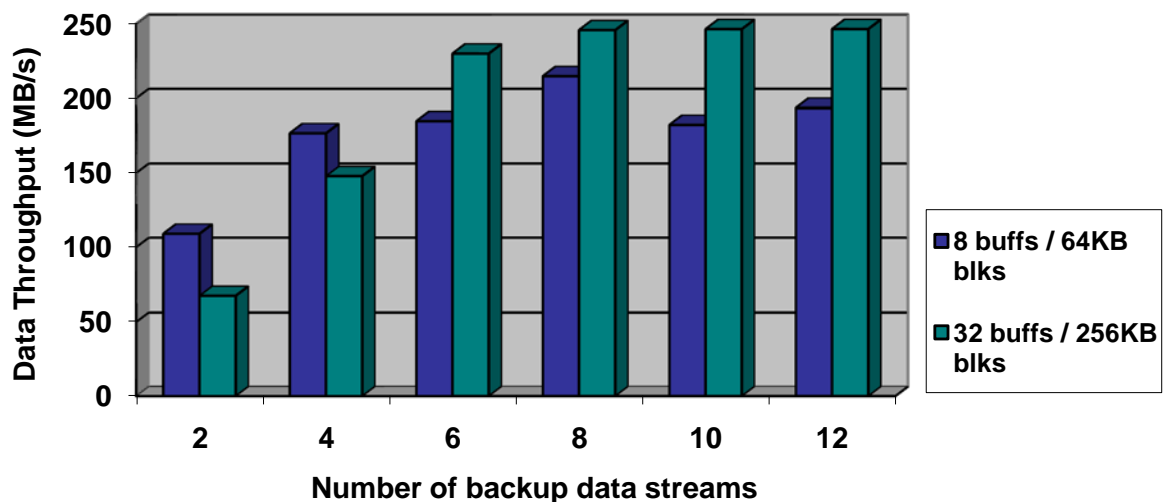
HP StorageWorks Ultrium 1840 LTO-4 limit testing

For optimal performance with tape devices, the most important contributing factor is providing data streaming continuously at the maximum throughput capacity of the device. If continuous data streaming to the tape device is not maintained, the device must stop media movement, reposition the media, and then restart the media when sufficient data is available to write to the media. These stop/reposition/restart cycles not only decrease throughput performance but also can cause excessive media and device wear.

The HP StorageWorks Ultrium 1840 LTO-4 tape device can transfer data at a rate of 240MB/s (assuming 2:1 compression). The HP LTO-4 drives include HP's exclusive Data Rate Matching feature, which further optimizes performance by matching the host system I/O data speed to keep drives streaming consistently. This enables the tape drives to be one of the fastest in the industry today.

Figure 4 shows results of stress testing performed to identify the maximum I/O throughput rate to one HP LTO-4 tape drive. The tests use the same data type and mix specified for other tests performed for the characterization project. The more compressible the data, the higher the I/O throughput rate to the tape media. With less compressible data, the I/O throughput rate decreases toward the native speed of the tape device. The HP LTO-4 devices have a native I/O rate of 120 MB/s.

Figure 4: HP StorageWorks Ultrium 1840 LTO-4 tape drive stress test results



The test results in Figure 4 indicate that, given the backup data mix being used for these tests, eight data streams from clients is optimal to keep a LTO-4 tape drive streaming at maximum speed. More data streams can be used in parallel to the device, but the overall backup time may actually be longer if any of the backup tape devices are left unused or only partially used. Configuring more active parallel data streams than is optimal can also result in longer restore times, as the backup data for one client is interleaved throughout a longer portion of the backup media.

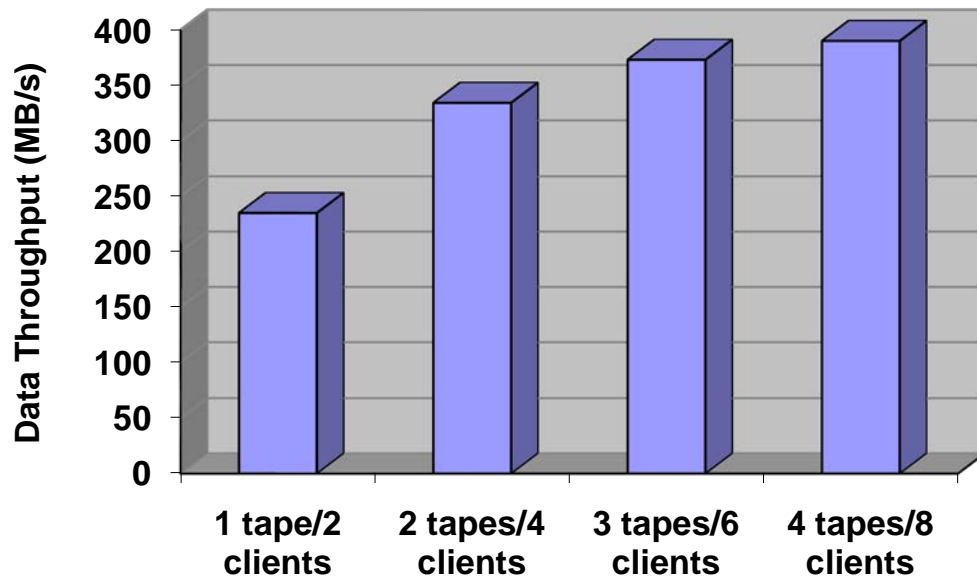
These results show that the backup utility tuning combination of 8 buffers and 64KB I/O blocks, which was optimal for the single client 1GbE port in tests reported previously, is not optimal for maintaining data streaming to an LTO-4 tape device. Because the goal is to optimize backup data throughput from the clients across the network to the backup tape devices, these tests show that the optimal

combination for backup utility tunable settings is 32 buffers and 256KB I/O blocks. Again, because optimal tuning may vary from one backup server environment to another, similar tuning analysis should be performed for each specific environment.

4Gb FC HBA port limit testing

Characterization and limit stress testing of the 4Gb FC port involved connecting tape devices in scale-up succession to a single 4Gb FC port until obtaining the maximum port throughput. For each tape device added, two additional clients were added to direct data to it. Each client provided four data streams. Figure 5 shows the results of the stress testing.

Figure 5: 4Gb FC HBA port throughput limit testing



The results show that a single LTO-4 tape device connected to a 4Gb FC port was able to attain an average of 225 MB/s. When a second tape device is added to the same 4Gb FC port, the total throughput achieved was about 334 MB/s, or an average of 167 MB/s per device. Scaling up to four LTO-4 tape devices resulted with a total maximum throughput of about 390 MB/s. This is very close to the maximum 4Gb FC port throughput of 410 MB/s that was achieved with other HBA performance-optimized tests. For more information about 4Gb FC HBA performance and scaling, see the “AB379B – PCI-X Dual Channel 4Gb/s Fibre Channel Adapter” white paper at the following location:

<http://bizsupport1.austin.hp.com/bc/docs/support/SupportManual/c02019292/c02019292.pdf>

While these tests identified the port throughput limit by using four LTO-4 tape devices connected to a single 4Gb FC port, this is not a recommended configuration. To achieve optimal device throughput, connect no more than two LTO-4 tape devices per 4Gb FC port. A single 4Gb FC port does not have enough I/O throughput bandwidth to sustain concurrent optimal throughput to more than two LTO-4 tape devices.

Test results: implications for optimizing the test environment

The results of the various limits, stress, and tuning tests described previously help define an optimal configuration for the network backup server test environment.

The backup server configuration includes two 4Gb FC dual-port HBAs (four ports in total) and four HP LTO-4 tape devices. For maximum throughput in this configuration, the LTO-4 tape devices are connected so that each tape device has its own dedicated FC port.

Testing shows that the network bandwidth limit for each client system's 1GbE port is about 113 MB/s. Although focused testing shows that three concurrent data streams on the client can sustain saturation of the 1GbE port at 113 MB/s, configuring four parallel data streams on each client accommodates temporary lags in any individual data stream, ensuring consistent, maximum client data-transfer rates to the backup server.

Using a backup utility tuning combination of 32 buffers and 256KB I/O block size, along with the established test data mix, the 113 MB/s maximum throughput capability of a single client's 1GbE port factors conveniently in the measured 225 MB/s average sustained backup I/O rate of the HP LTO-4 tape devices. Thus, with two clients, each having four concurrent data streams, this configuration can achieve an average total throughput of about 226 MB/s (2 clients * 113 MB/s) of backup data to a single HP LTO-4 tape device.

Eight clients are required to drive the four LTO-4 tape devices at optimal throughput (each LTO-4 tape device paired with two clients, each client providing four data streams).

These findings determined the final hardware and software configuration for the test environment shown in Figure 1. Because each unique backup server environment includes different client systems and unique network and tape throughput characteristics, similar testing and tuning analyses should be performed to ensure maximum efficiency.

Analysis of test results for backup servers and client systems

Results of the characterization testing are split into two sections, one section for the backup servers and the other for the client systems used in the test configuration.

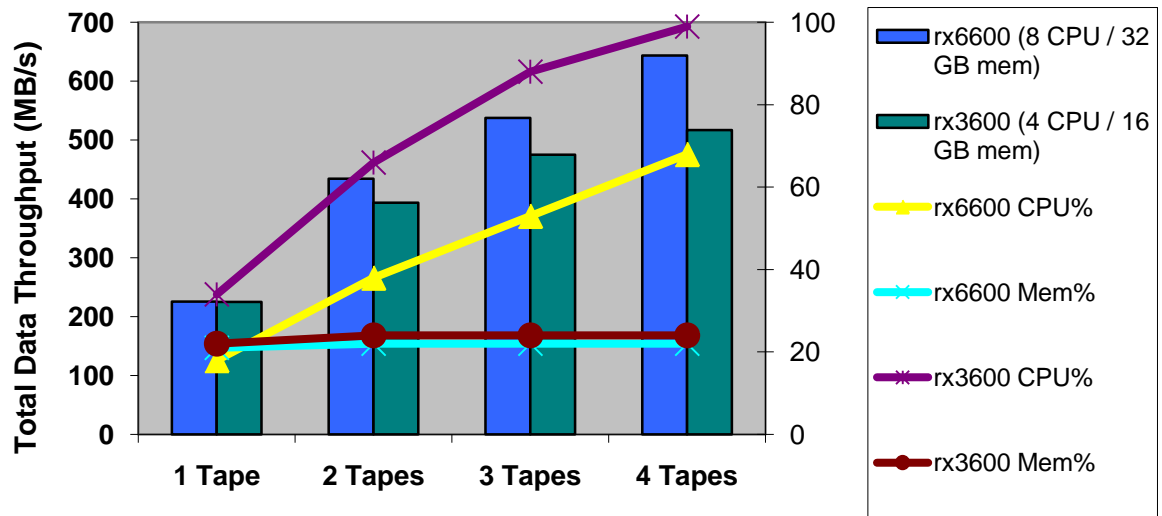
Backup server results

The tests compared the rx3600 and rx6600 Integrity server performing as a backup server. The tests also compared the backup and restore performance of the rx3600 backup server model.

Comparing rx3600 and rx6600 backup server performance

Figure 6 shows the backup server performance achieved for the rx3600 and rx6600 Integrity servers, using the Data Protector backup utility and from one-to-four tape devices per server. For each tape device configuration, the figure shows the total data throughput per server, along with the associated CPU utilization (CPU %) and memory utilization (MEM %).

Figure 6: Data Protector backup server performance comparing rx3600 and rx6600



The rx3600 server configuration has half the processors and memory of the rx6600 configuration. The chart above shows that the performance scaling of the rx3600 server is eventually limited by the amount of processing power available. With four LTO-4 tape devices, the rx3600 reaches 99% CPU utilization while achieving about 500 MB/s total data throughput; in contrast, the rx6600 reaches about 70% CPU utilization while achieving about 643 MB/s total data throughput.

For both servers, CPU utilization increases with additional tape devices, while memory utilization remains at about 23%.

Given that the rx6600 server is only at 70% CPU and 23% memory utilization with four LTO-4 tape devices, additional capacity is available to scale further for servicing a larger client base or hosting additional mission critical services.

Comparing backup and restore performance – rx3600 backup server

A decade ago, the general rule was that restore operations would take about twice as long as backup operations. The main reason for this difference is that the restore requires additional time to allocate storage blocks for the data and for writing that data to disk on the client. Also at that time, tape devices and the I/O infrastructure were much slower in throughput capability, enabling the file systems to keep up with the restore data rate for recovery operations.

Today, the I/O infrastructure and devices, especially tape devices, have significantly increased in speed and capacity (ever more so within the last few years), making backup operations much faster overall. As a result, I/O infrastructure and tape devices are no longer the limiting factors for a restore operation. Now the limiting factors tend to be the file system layer and the writing of data to disk.

To compare the restore performance of the tape devices and I/O infrastructure with the performance of the file system and its associated overhead for allocating files and writing file data to storage, a series of different restore methods were performed:

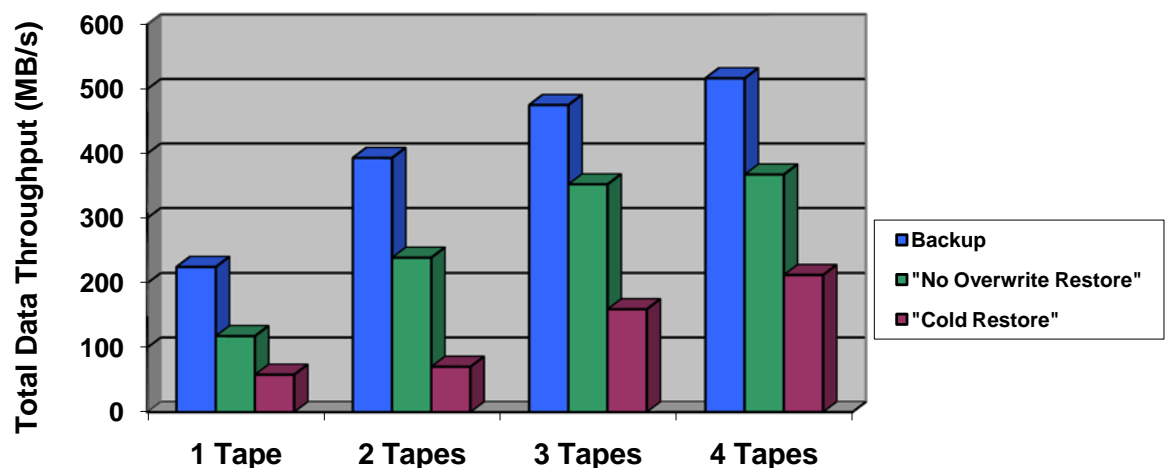
- One set of restores left the client file data in place and used the “No overwrite” option of Data Protector for the data restore operation (referred to hereafter as a “No Overwrite Restore”). A “No Overwrite Restore” restores only the missing files in a file system and retains existing files. With the “No Overwrite Restore” operation, Data Protector simply reads data from tape on the backup server and transmits the data over the network to the client; because the files already exist on the client system, they are not written to the client’s file system and disk. This confines measurement of the restore performance to the tape devices and the network infrastructure only, eliminating the effect of file system, data write latencies, and disk bandwidth limitations.
- Another set of restores was performed after deleting from the client file systems all the data files that were backed up. The restores were run using the default options of Data Protector. Because previously backed-up data no longer exists in the client system’s file system, all data in the backup is restored (hereafter referred to as a “Cold Restore” operation). The “Cold Restore” operation reads from tape and transmits backup data from the backup server to the client, taking additional time to allocate the “new” files in the client file system, to allocate file extents, and to write all the file data to the client’s storage.

Note

The overall restore performance of the client file systems could likely be improved with specific tuning on the client systems; however, the objective of this particular network backup characterization was to leave tuning optimal for the applications and services that are the primary function of the client system.

Figure 7 shows the results comparing backup and restore performance using the rx3600 backup server. The data backup and the two restore operations mentioned previously (“No Overwrite Restore” and “Cold Restore”) were each tested with an increasing number of tape devices (from one to four).

Figure 7: Comparing backup and restore performance using an rx3600 server



The “No Overwrite Restore” operation (which excludes actual writing of restore data to the file system and disk) scales well, averaging two-thirds of the backup throughput performance. The results of the “Cold Restore” operations show the effect that writing data to the file system and disk has on the

restore performance. The results confirm that the I/O infrastructure and tape devices are no longer the limiting factors for restore operations. With the added overhead of writing to the file system and storage, restore throughput averages about one-third of the backup performance.

Client server results

While this performance characterization effort focuses mostly on the backup server, valuable information was collected on the client systems. To recap, eight client systems were used to provide backup data to a network backup server. Each client system sends four concurrent data streams over a single 1GbE port at approximately 113 MB/s. The network backup server has eight aggregated 1GbE ports, providing a dedicated network link for each client system's data. The data streams from each pair of clients — eight data streams in total per pair of clients — are configured so that they are written to one LTO-4 tape device for backup. This same backup media is used for the restore characterization tests, where data for pairs of clients is restored concurrently.

To prevent distortion of the performance results, no other activities or applications were run on the client systems during the backup and restore operations. The following subsections summarize the most salient results.

Comparing SAS and SAN connected storage of client data

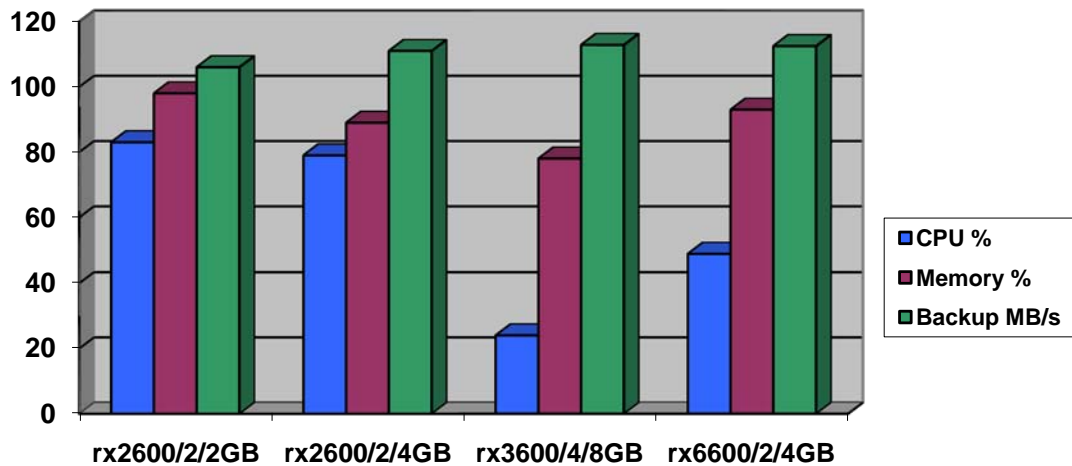
Another opportunistic objective of this characterization effort was to determine whether locating client data on directly-attached SAS storage or SAN-fabric-connected storage significantly affects backup and restore performance. For both backup and restore operations, no performance differences were perceived. The most interesting finding is that the major performance-limiting factor is the amount of memory in the client, much more so than the amount of CPU available and the type of storage interconnect.

Client backup performance statistics

Figure 8 shows client-level backup performance statistics for four different client configurations:

- rx2600, 2 processors, 2 GB memory
- rx2600, 2 processors, 4 GB memory
- rx3600, 2 dual core (4 CPUs), 8 GB memory
- rx6600, 1 dual core (2 CPUs), 4 GB memory

Figure 8: Client backup statistics using Data Protector



The graph in Figure 8 indicates that for backup operations, system memory is a greater limiting factor than CPU or storage connectivity type. The rx2600 system with 2 GB of memory was able to achieve only 106 MB/s of backup data throughput before being limited by memory (memory utilization reached 98%). Processing power on this two-processor system reached slightly over 80% utilization, showing that the two processors on this client had plenty of processing capacity to saturate a 1GbE port for network backup. Note that with an additional 2 GB of memory, the two-processor rx2600 system was more capable of attaining saturation of the 1GbE port limit of 113 MB/s.

For optimal network backup throughput for a client using a 1GbE port, the results suggest using a minimum of two CPUs and 4 GB of memory for each client.

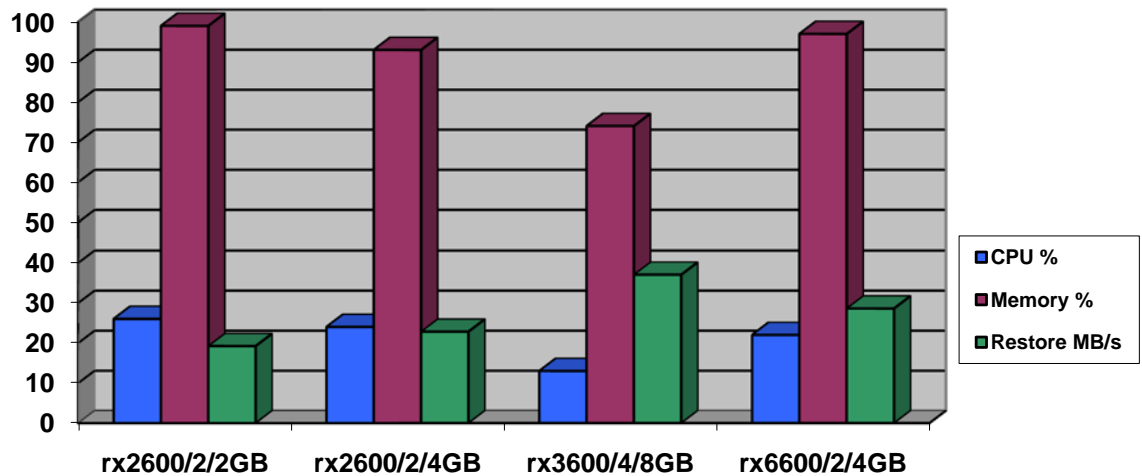
Client restore performance statistics

The main limiting factor with data restore is writing the restored data to storage through the file system. The same conclusions from the backup operation are true for restore operation: the more memory available in the system, the better is performance of the restore operation.

Figure 9 shows the restore throughput results for each of the four client configurations.

The server with the most memory — the rx3600 client system with 8 GB of memory — has the highest data restore throughput performance.

Figure 9: Client restore statistics using Data Protector



While tuning of client systems for backup and restore was not included in this backup server characterization effort, application performance and backup/restore performance on the client system might be optimized further by using the HP-UX `vxtunefs` command.

Best practices

This section describes the most notable best practices derived from the backup server characterization, including:

- HP-UX 11i v3 features and capabilities that helped greatly with metrics gathering and storage I/O management
- Considerations and techniques for private backup network configuration, tape library configuration, and other backup utility capabilities

Taking advantage of HP-UX 11i v3 features

HP-UX 11i v3 delivers a number of features that benefited this backup/restore performance characterization effort, including the ability to:

- Display I/O throughput for tape devices (`sar -t`)
- Display I/O throughput for I/O ports (`sar -H`) to view I/O spread across all HBA ports
- Display all paths to a specific device (`ioscan -m lun`)
- Set a specific I/O path for tape devices (`scsimgr set_attr -a lpt_to_lockdown`)
- Use single, persistent DSFs per device (SAN agility of Device Special Files, using binding of LUN WWIDs)

- Control interrupts (using the `intctl` command to manage interrupt configuration and handling)

The newly re-architected Mass Storage Stack released with HP-UX 11i v3 delivers significant, new benefits for tuning I/O and displaying metrics, whether being used with a network backup server or for direct or SAN-based backup. The richness of tuning capabilities and overall I/O agility makes HP-UX 11i v3 an ideal choice for backup servers, providing protection and recoverability of your business's most important asset—your business-critical data.

Several white papers provide useful information and details about the HP-UX 11i v3 Mass Storage Stack functions and features, including additional details for the commands and features mentioned in the following subsections. White papers recommended for reference include:

- "Overview: The Next Generation Mass Storage Stack"
- "scsimgr SCSI Management and Diagnostics utility on HP-UX 11i v3"
- "HP-UX 11i v3 Native Multi-Pathing for Mass Storage"
- "HP-UX 11i v3 Mass Storage Device Naming"
- "HP-UX 11i v3 Persistent DSF Migration Guide"
- "HP-UX 11i v2 to 11i v3 Mass Storage Stack Update Guide"

These white papers can be found at the following location:

<http://www.hp.com/go/hpux-core-docs>
(click on the HP-UX 11i v3 product link)

For additional details and usage information, refer to the manpage for each command.

Displaying I/O throughput for tape devices (`sar -t`)

The `sar -t` option is an invaluable tool for backup/restore performance characterizations and for viewing I/O metrics for tape devices. This command displays the actual throughput (in MB/s) to connected tape devices. The `sar -t` command is much more precise for measuring backup I/O throughput rates than the standard practice of dividing the volume of backed-up data by the overall backup time reported by the backup utility. The overall backup time reported by backup utilities often includes backup process startup/stop time and tape mount/positioning time, which skew the results to a backup I/O throughput estimate that is lower than the actual throughput.

The following is an example of `sar -t` command output, showing the Read and Write I/O throughput in MB/s:

```
# sar -t 10 3
```

```
HP-UX hpsas003 B.11.31 U ia64      06/27/09
```

14:23:41	device	%busy %age	r/s num	w/s num	read MB/s	write MB/s	avserv msec
14:23:51	tape12_BEST	97.30	0	901	0.00	225.25	1
14:24:01	tape12_BEST	97.20	0	903	0.00	225.75	1
14:24:11	tape12_BEST	97.10	0	902	0.00	225.50	1
Average	tape12_BEST	97.20	0	902	0.00	225.50	1

```
#
```

Displaying I/O throughput for I/O ports (`sar -H`) to view I/O spread across all HBA ports

The new `sar -H` option released with HP-UX 11i v3 displays HBA port-level statistics, such as the number of I/Os for the port, data Read MB/s, data Write MB/s, and overall I/O throughput over the port (MB/s). It enables you to monitor HBA port hotspots and to determine whether additional HBA

ports or paths should be added to the system for greater throughput and efficiency. This characterization benefited immensely from the ability to capture client data read and write metrics for backup and restore operations on the client systems.

The following is an example of `sar -H` command output. In addition to displaying the number of I/O operations per second (as does the `sar -d` command), the `sar -H` command displays more details about Reads and Writes.

```
# sar -H 10 3

HP-UX hpsas002 B.11.31 U ia64      06/29/09

13:36:39      ctlr      util t-put  IO/s    r/s     w/s    read  write avque avwait avserv
              %age      MB/s    num     num     num  MB/s   MB/s   num   msec   msec
13:36:49    sasd1      100   35.52   570      0    570   0.00   35.52    1     0     6
13:36:59    sasd1      100   35.32   566      0    566   0.00   35.32    1     0     6
13:37:09    sasd1      100   35.34   567      0    567   0.00   35.34    1     0     6

Average    sasd1      100   35.39   568      0    568   0.00   35.39    1     0     6
#
```

Displaying all paths to a specific device (`ioscan -m lun`)

The new `ioscan -m lun` option provided by HP-UX 11i v3 allows you to display all the lunpaths for a particular LUN on the system. This helps determine which tapes are accessible, through which I/O ports, and displays all the lunpaths to each tape device. Displaying the lunpaths enables you to copy and paste long lunpaths for use with `scsimgr` commands.

The following is an example of `ioscan -m lun` command output:

```
# ioscan -m lun /dev/rtape/tape12_BEST
Class      I  Lun H/W Path  Driver  S/W State  H/W Type  Health  Description
=====
tape       12 64000/0xfa00/0x18a  estape  CLAIMED   DEVICE    online   HP
Ultrium 4-SCSI
          0/3/0/0/0/1.0x500110a0008b9f72.0x0
          0/3/0/0/0/1.0x500110a0008b9f73.0x0
          0/7/0/0/0/1.0x500110a0008b9f72.0x0
          0/7/0/0/0/1.0x500110a0008b9f73.0x0

          /dev/rtape/tape12_BEST  /dev/rtape/tape12_BESTn
          /dev/rtape/tape12_BESTb /dev/rtape/tape12_BESTnb
#
```

Note

The tape device with a Persistent DSF of `/dev/rtape/tape12_BEST` has four lunpaths (two beginning with `0/3/0...` and two beginning with `0/7/0...`) to the physical device. All are represented with this single Persistent DSF.

Setting specific I/O path for tape devices (`scsimgr get_attr / set_attr / save_attr`)

The `scsimgr` command on HP-UX 11i v3 is a very powerful management tool for monitoring and managing storage connectivity of the server and for displaying various I/O metrics for connected storage devices, including tape devices. Load balancing of I/O for tape devices is performed using the “path lockdown” algorithm (using the `lpt_lockdown` device attribute), which automatically balances lockdown of tape lunpaths across the available HBA ports.

In some cases, the default automatic load balance allocation of tape lunpaths across the available I/O ports might not be optimal. You can override the default auto balancing of “path lockdown” for

tape devices by using `scsimgr save_attr` or `scsimgr set_attr` to manually set the tunable `lpt_to_lockdown` attribute to the desired lunpath to use for accessing the tape device. The settable `lpt_to_lockdown` attribute for tuning tape device access was introduced in HP-UX 11i v3 update 4 (Fusion 0903). The `scsimgr get_attr` command displays the current load balancing policy in effect and the associated I/O path that is locked down for a particular tape device.

The `scsimgr get_attr` command is also very useful for displaying the tape device's LUN WWID and configured LUN ID for correlation of the associated tape device within the tape library. Most tape library management tools display tape device WWIDs and the actual physical location of the tape device within the tape library.

In the following examples, the `scsimgr` command displays and alters the current load balancing settings, which for tape devices is the lunpath locked down for I/O access to the serial tape device. In the first example that follows, the `scsimgr get_attr` command displays both the default read-only `lpt_lockdown` and the settable `lpt_to_lockdown` device attributes. This informs you of the current and saved settings used for accessing the tape device represented by the DSF

```
/dev/rtape/tape12_BEST:
```

```
# scsimgr get_attr -D /dev/rtape/tape12_BEST -a lpt_lockdown -a lpt_to_lockdown
```

```
SCSI ATTRIBUTES FOR LUN : /dev/rtape/tape12_BEST
```

```
name = lpt_lockdown
current = 0/3/0/0/0/1.0x500110a0008b9f72.0x0
default =
saved =
```

```
name = lpt_to_lockdown
current =
default =
saved =
```

```
#
```

Note that in the preceding output the tunable `lpt_to_lockdown` has no value. This means it has not been set, and so the default `lpt_lockdown` load balancing algorithm is in effect. When the tape device is next opened, a lunpath on a FC port with the least I/O load will be allocated by default for access to the tape device. The path currently being used or, if the device is not currently opened, that was last used, is shown as the current setting for the read-only `lpt_lockdown` device attribute.

If you want to override the default `lpt_lockdown` lunpath allocation, you can set the tunable device attribute `lpt_to_lockdown` to the lunpath hardware path for the tape device that you prefer to use for I/O access. It is easiest to display the lunpath hardware paths for the tape device by using the `ioscan -m lun` command, and then copy the lunpath hardware path of the preferred device and paste it in the `scsimgr` command line.

Use the following command to set and save across reboots the lunpath hardware path

```
/7/0/0/0/1.0x500110a0008b9f73.0x0 for I/O to the tape device
```

```
/dev/rtape/tape12_BEST:
```

```
#
```

```
# scsimgr save_attr -D /dev/rtape/tape12_BEST
-a lpt_to_lockdown=0/7/0/0/0/1.0x500110a0008b9f73.0x0
```

```
Value of attribute lpt_to_lockdown saved successfully
```

```
#
```

To verify the setting of the lunpath for the next use of the tape device `/dev/rtape/tape12_BEST`, reissue the `scsimgr get_attr` command as used in the first example of this section. This displays the `lpt_lockdown` and `lpt_to_lockdown` attributes for the device, as in the following example:

```
#
# scsimgr get_attr -D /dev/rtape/tape12_BEST -a lpt_lockdown -a lpt_to_lockdown

      SCSI ATTRIBUTES FOR LUN : /dev/rtape/tape12_BEST

name = lpt_lockdown
current = 0/7/0/0/0/1.0x500110a0008b9f73.0x0
default =
saved =

name = lpt_to_lockdown
current = 0/7/0/0/0/1.0x500110a0008b9f73.0x0
default =
saved = 0/7/0/0/0/1.0x500110a0008b9f73.0x0

#
```

Note

The tunable `lpt_to_lockdown` device attribute is now set to the designated lunpath hardware path specified with the `scsimgr save_attr` command.

Using Persistent DSFs

One of the invaluable features of HP-UX 11i v3 is the availability of Persistent DSFs, which are bound by using the LUN WWID of the storage device. When any SAN changes are made, the Persistent DSFs remain unchanged and valid for device access. During testing, a check was made to see whether swapping the two dual 4Gb FC HBAs for two other FC HBAs in different I/O slots would cause an issue. With the swapping of the HBAs and re-connection of the FC links, an `ioscan` showed that the tape devices had retained their original Persistent DSFs. Thus, no configuration changes were required on the system or on the backup utilities accessing the tape devices.

Controlling interrupts (`intctl`)

The `intctl` command allows you to display and modify interrupt assignments for the CPUs in the system. As part of this characterization effort, `intctl` was used to determine whether manual changes of interrupt assignments could optimize backup I/O throughput on the backup server. In addition to testing with the default interrupt assignment, the `intctl` command was used to evaluate two additional interrupt handling strategies:

- Spread evenly across all CPUs the interrupts of the 1GbE ports and FC ports in use for the backup
- Collocate interrupts for the 1GbE ports and the FC port associated with a tape device on the same CPU

Test results on the rx3600 and rx6600 servers revealed minor differences between the interrupt handling strategies in overall backup I/O throughput for these systems. The differences were not significant enough to recommend any changes. In fact, the default interrupt configuration allocation was frequently the best strategy for the many backup operations performed with this characterization effort. However, although changing the interrupt-handling configuration did not show benefit with the entry-level backup server test characterization, it may have a positive effect for other workload types or with larger server configurations.

Tape library and device considerations

The HP StorageWorks ESL 712e tape library accommodates a variety of SAN topologies for configuration. For switched FC connections of tape devices to the backup server, use the management interface to ensure that the tape drive port settings are set to “Fabric” for each of the tape devices. In the test configuration, two tape devices were initially configured erroneously as “loop”, which negatively affected overall throughput to the device.

The tape library management interface is also useful for displaying the WW port names and the LUN WWID associated with each tape drive and library robotic device. This information helps you determine the DSF or Logical Device Name configured for the device in the backup utility.

Balancing backup data streams

Backup utilities usually provide an option for auto-balancing of all clients’ backup data streams across the available backup devices and media. Some backup utilities’ auto-balancing algorithms might spread data streams from a specific client across multiple backup devices and media, making data recovery slower and more complex, requiring multiple units of backup media to complete. For faster and less complex recovery, HP recommends making the additional effort to (1) verify that each client’s data is not being undesirably spread across multiple backup devices and media, and if necessary, (2) to manually segment and balance the client backup data streams to be more appropriate for quick restore. Optimal recovery of data is most essential for enabling business continuity and continued accessibility to your critical data.

Also, consider making post-backup copies of each client’s backup data for collocation of client data on a single unit of media, enabling a much less complex recovery operation when required. This is especially important for the most business-critical application servers, as recovery of these servers must happen as quickly as possible.

Private backup network considerations

In real customer environments, network-based backup and restore of client data is often performed over the primary, shared network. During this characterization effort, the backup and restore operations were performed over a private, dedicated 1GbE network to prevent the results from being skewed by traffic congestion that might occur over a shared network.

Backup utilities are designed and optimized for use over the systems’ primary network connection, as most systems appropriate for network backup typically have only one network port. With client configurations for network backup, backup utilities typically resolve to the shared, primary network of the client. For backup operations, these configurations usually use the first network link associated with that client’s host name, unless specifically overridden. While most backup utilities provide configuration capability to perform backup and recovery over alternate (non-primary) network connections, additional manual configuration changes are typically required. For example, you might need to add the private network client and backup server IP names to the `/etc/hosts` file, and create or modify the `/etc/nsswitch.conf` file to include search of files and use of a DNS server or other IP name resolution options (if DNS service is unavailable on the private network).

For use of the private network, Data Protector requires that you manually edit the `cell_server` (`/etc/opt/omni/client/cell_server`) configuration file on each client to reflect the private network name for the backup server. This enables backup data from clients to be sent over the private network to the backup server. Restore operations over a private network do not require additional configuration changes.

Monitoring link utilization of APA

When using a network link aggregation such as HP Auto Port Aggregation (APA), HP recommends initial monitoring of the network traffic on the physical links to ensure the network traffic is being balanced as expected. To display the inbound and outbound network traffic of individual network links, you can use tools such as Glance (-l option), the network switch management utility, or your selected performance measurement utility. Monitor the individual physical network link loads for both backup and restore operations, and ensure the system and network link aggregation configurations are balancing the backup/restore data properly across the physical links. Once initial setup and configuration is completed, occasionally monitor the network link loads to ensure continued optimal network load balancing and throughput.

For additional information about Auto Port Aggregation (APA) on HP-UX, see the “HP Auto Port Aggregation Administrator's Guide: HP-UX 11i v3”, available with the following link:

<http://docs.hp.com/en/J4240-90045/J4240-90045.pdf>

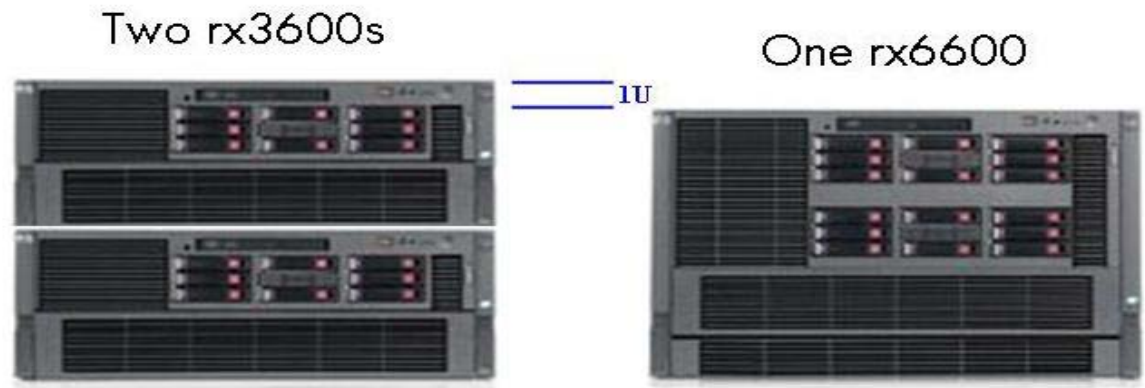
Considering the uniqueness of each backup environment

Every backup environment, including the configured client systems, is unique and might show different results than presented in this white paper. HP recommends that you perform a similar tuning analysis and optimization effort with each specific backup environment to determine the most optimal settings and configuration for that unique environment.

Minimizing the server hardware footprint in the data center

To reduce the backup server hardware footprint, we compared the footprints and performance of two rx3600 backup servers against one rx6600. Figure 10 shows the footprint of the dual-rx3600 backup server setup relative to a single rx3600 server.

Figure 10: Footprint of two rx3600s vs one rx6600



The smaller, yet very powerful rx3600 has a height of 4U EIA (Electronic Industries Association) units, while the rx6600 has a height of 7U. As shown in Table 1, the rx3600 delivers an amazing 517 MB/s (or 1.77 TB/hr) of network backup throughput with four LTO-4 tape drives. In contrast, the rx6600 can deliver 643 MB/s (or 2.2 TB/hr) of network backup throughput. It still has the processing power and system resources to scale further or to perform additional business-critical services.

Table 1: Comparing rx3600 and rx6600 performance

Backup Server Model	CPU	Memory	Server Height	Network Backup Throughput	Network Backup Throughput
Integrity rx3600	2 dual-core 9140M processors	16 GB DDR2	4U EIA units	517 MB/s	1.77TB/hr
Integrity rx6600	4 dual-core 9140N processors	32 GB DDR2	7U EIA units	643 MB/s	2.2TB/hr

For those concerned with footprint space in the data center, consider using two rx3600 servers running HP-UX 11i v3. Two rx3600 servers require a total height of 8U (EIA units)—only 1U EIA unit more than the height of a single rx6600. The dual-rx3600 configuration yields a remarkable total network backup throughput of 1034 MB/s (or over 3.5 TB/hr) compared to the single rx6600 server's 643 MB/s (or 2.2 TB/hr) throughput for about the same footprint. In addition, when the two rx3600 servers are configured as part of an HP Serviceguard cluster, they can provide highly-available data protection services.

Optimizing for mission-critical applications and high-demand environments

Network-based backup using a backup server is only one of many possible backup/recovery methods to consider as you formulate your overall data center backup and recovery strategy. For applications

and services that require faster backup and recovery, consider SAN-based backup made directly to tape devices on the SAN, Zero Downtime Backup (ZDB) solutions, and other possible methods available from HP.

In particular, ZDB adds more flexibility to your enterprise data-center backup strategy and can help satisfy the needs of the most demanding of applications environments and services by fully offloading the backup overhead and data contention from your production environment. You can use rx3600 and rx6600 Integrity servers for ZDB solutions. For additional information about Data Protector's Zero Downtime Backup solutions, see the "Zero Downtime Backup Concepts Guide":

<http://h20000.www2.hp.com/bc/docs/support/SupportManual/c01631247/c01631247.pdf>

For more details about this and other strategies and tools for mission-critical, high-demand application environments, contact your HP sales representative.

Summary of test results

This backup server characterization effort tested the performance of the rx3600 and rx6600 Integrity servers as backup servers, running HP-UX 11i v3 and using the HP Data Protector backup utility along with the most commonly deployed datacenter technologies. Various configurations were tested to determine potential stress points and limits to throughput and to develop an optimal backup strategy. Tests also determined optimal tuning practices for the backup server, OS, and backup utility.

The base configuration and test environment for the characterization effort was a single backup server with four LTO-4 tape drives, and eight client systems providing the backup/restore data over a 1GBE-based private network.

For client data storage, no significant performance difference was observed for either backup or restore operations when using SAS or SAN connected storage.

Most noteworthy, tests demonstrated that the rx3600 and rx6600 Integrity servers perform superbly for network backup and restore operations. With four LTO-4 tape devices for backup, and exploiting the advantages of the HP-UX 11i v3 operating system, the rx3600 delivers 517 MB/s or 1.77 TB/hr of network backup throughput, while the rx6600 delivers 643 MB/s or 2.2 TB/hr. Using two rx3600 servers yields a fantastic total network backup throughput of 1034 MB/s or over 3.5 TB/hr, much more throughput than a single rx6600 server with almost the same rack space footprint.

The rx3600 Integrity servers have about half the processors and memory of the rx6600, but with one tape device, the rx3600 backup server performance was equivalent to that of the rx6600. With the other tested configurations (two, three, and four devices), the rx3600 backup server performance was comparable to that of the rx6600. The advantage of the rx6600 is additional CPU power that enables scalability to service a larger client base or to host additional mission-critical services.

Table 2 provides a summary of other significant test results.

Table 2: Summary of configurations recommended for optimal performance

Performance metric or optimal configuration	Recommended, optimal configuration	Notes
Tuning combination (buffers and I/O block size)	32 buffers and 256KB I/O blocks for LTO-4 tape devices	The 256KB I/O block size is recommended especially for systems that have the Online JFS product installed, as this block size implicitly enables the default setting for the Direct I/O feature of the file system, which improves backup performance.
Maximum backup data I/O throughput for a client over a single 1GbE NIC port	113 MB/s	This is also the maximum link speed for a 1GbE port. These results could be achieved with three concurrent data streams on the client; however, four concurrent data streams are recommended to make allowances for temporary lags in any individual data stream resulting from small files, disk agent delays, and so forth.
Maximum I/O throughput rate to one HP LTO-4 tape drive	Greater than 240 MB/s, with four data streams optimal from each of two clients	This assumes 2:1 compression. The more compressible the data, the higher is the I/O throughput rate to the tape media. HP's exclusive Data Rate Matching feature optimizes performance by matching the host system I/O data speed to keep the drives streaming consistently.
Optimal number of HP LTO-4 tape devices per 4Gb FC port	No more than 2 per 4Gb FC port	A 4Gb FC port can achieve approximately 410 MB/s I/O throughput. Two LTO-4 tape devices on one 4Gb FC port consumes about 334 MB/s of bandwidth, not leaving additional bandwidth for scaling of another LTO-4 tape device to run at optimal throughput.
Client hardware configuration for optimal backup performance	Minimum of 2 CPUs and 4 GB of memory	Tests used a 1GbE port. The amount of client memory affects performance most significantly, much more than the amount of CPU available and the type of storage interconnect. Client backup performance can be increased using HP-UX 11i v3 tuning features.
Client hardware configuration for optimal restore performance	Minimum of 2 CPUs and 4 GB of memory	The amount of client memory affects performance most significantly. The main limiting factor is writing out restored data to storage through the file system. Client restore performance can be increased using HP-UX 11i v3 tuning features.

General considerations and best practices

- Numerous features provided by HP-UX 11i v3 help optimize and monitor backup and restore performance, including:
 - Display I/O throughput for tape devices (*sar -t*)
 - Display of all paths to a specific device (*ioscan -m lun*)
 - Display I/O throughput for I/O ports (*sar -H*) to view I/O spread across all HBA ports
 - Set specific I/O path for tape devices (*scsimgr set_attr -a lpt_to_lockdown*)

- Single, Persistent DSFs per device (SAN agility of Device Special Files using binding of LUN WWIDs)
- Interrupt Control (management of interrupt configuration and handing with the *intctl* command)
- When using a network link aggregation such as HP Auto Port Aggregation (APA), initially monitor the network traffic on the physical links to ensure the network traffic is being balanced as expected. Once initial setup and configuration is completed, occasionally monitor the network link loads to ensure continued optimal network load balancing and throughput.
- Backup performance testing shows only a minor difference between auto-balancing and manual balancing of data streams for optimal backup throughput.
- To ensure optimal recovery of data, manually segment and balance the client backup data streams across multiple backup devices, rather than relying on auto-balancing.
- Make background copies of each client's backup data, storing them on a single storage device for collocation of client data, enabling a less complex recovery when required. This is especially important for the most business-critical application servers, as recovery of these servers must happen as quickly as possible.

Given that each backup/restore environment is unique, to determine the best settings and configuration for your environment, HP recommends that you perform tuning analyses and optimization tests similar to those performed in this characterization effort.

Conclusion

This characterization effort confirms that the HP rx3600 and rx6600 Integrity servers, running HP-UX 11i v3, make ideal, robust, and highly reliable network backup servers. In our testing environment, using commonly-used technologies, the smaller rx3600 delivers an amazing 517 MB/s (1.77 TB/hr) of network backup throughput, while the rx6600 delivers 643 MB/s (2.2 TB/hr) of network backup throughput. The rx6600 has plenty of processing power and system resources to scale further or to perform additional business-critical services. If hardware footprint space is a concern, two rx3600 servers could be configured for network backup in place of an rx6600, occupying almost the same footprint while delivering an astounding total network backup throughput of 1034 MB/s (over 3.5 TB/hr). What is more, when the two rx3600 servers are configured as part of an HP Serviceguard cluster, they can provide highly-available data protection services.

Table 3 summarizes the differences between an rx3600 and rx6600 server.

Table 3: Network Backup Throughput for rx3600 and rx6600 servers

Backup Server	CPUs	Memory	Server Height	Network Backup Throughput MB/s	Network Backup Throughput TB/hr
Integrity rx3600 server	2 dual-core 9140M processors	16 GB DDR2	4 EIA units	517 MB/s	1.77 TB/hr
Integrity rx6600 server	4 dual-core 9140N processors	32 GB DDR2	7 EIA units	643 MB/s	2.2 TB/hr

The backup and restore functionality of these servers benefits immensely from the extensive tuning capabilities and I/O agility of HP-UX 11i v3. These capabilities, coupled with the unsurpassed level of reliability and robustness of Integrity servers, provides the best possible protection and recoverability of your business' most important asset, your business-critical data. In addition, to add more flexibility to your enterprise data center backup strategy, both of these servers can be used for Zero Downtime Backup (ZDB) solutions for the most demanding applications environments and services.

For more details about these and other strategies and tools for mission-critical, high-demand application environments, please contact your HP sales representative.

For more information

For additional information and details about HP products and solutions discussed in this white paper, please visit the following web locations:

- HP Integrity Servers: www.hp.com/products1/servers/integrity/index.html
- HP-UX 11i v3: www.hp.com/go/HPUX11iv3
- HP-UX 11i v3 Mass Storage Stack Features: <http://www.hp.com/go/hpux-core-docs>
(click on the HP-UX 11i v3 product link)
- HP Data Protector: www.hp.com/go/DataProtector
- HP Fibre Channel Host Bus Adapters:
www.hp.com/products1/serverconnectivity/storagesnf2/index.html
- HP StorageWorks Ultrium LTO-4 Tape Devices and Tape Libraries: www.hp.com/go/Tape
- HP Pro-Curve Switches: <http://www.procurve.com>



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