Oracle Maximum
Availability Architecture

Zero Data Loss Recovery Appliance Performance Proof of Concept

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Introduction

Oracle's Zero Data Loss Recovery Appliance (Recovery Appliance) is a ground-breaking data protection solution that tightly integrates with the Oracle Database. It eliminates data loss exposure and dramatically reduces data protection overhead on production servers. In addition, the Recovery Appliance scales to protect thousands of databases, ensures end-to-end data validation, and implements full lifecycle protection including disk backup, tape backup, and remote replication.

This white paper highlights the results of a proof of concept conducted by Oracle MAA Best Practices and Recovery Appliance Development, Oracle Solution Centers, and North America Commercial Engineered Systems (NACES) Proof and Engineering teams, working with a large enterprise customer who faced a number of backup and recovery challenges in their 15,000+ Oracle databases environment.

At the time of the proof of concept, the customer's backup strategy consisted of:

- RMAN database backups (daily level 0, or weekly level 0 + daily level 1) to local storage (SAN, NAS, etc.) where they were retained for approximately two weeks.
- Local backups swept weekly by a non-Oracle backup product (from Vendor 1) to a non-Oracle deduplication appliance (from Vendor 2) for 30 day retention, then replicated to another deduplication appliance residing at their disaster recovery site, where backups were then copied to physical tape to meet retention needs beyond 30 days.

The customer's main challenges were:

- Maintaining a very large local storage allocation deployed in a siloed fashion for the 15,000+ databases.
- Inability to coordinate the sweep schedule of the Vendor 1 non-Oracle product with RMAN backups being fully completed, resulting in incomplete database backups on the Vendor 2 non-Oracle product or tape, and ultimately, failures during restore operations.
- Greater than 48 hours Recovery Time Objective (RTO) to restore from tape due to various manual steps performed by DBA and storage groups. These steps included: identifying needed tapes at the bunker site, restoring the backups as-is to a temporary disk location, copying those backups to the primary site, and finally, cataloging the backups with RMAN before running database restore operations.

In summary, the customer's non-Oracle-integrated, multi-step backup approach significantly increases the complexity and risk of database restore operations.

This proof of concept shows how the customer's challenges can be addressed by the Recovery Appliance, and how the their performance testing goals—outlined in the section that follows—were met, and in fact, exceeded.

Proof of Concept Goals

The overall objective of the proof of concept was to demonstrate that Recovery Appliance can protect a large number of databases while meeting the customer-specified performance criteria.

The individual goals were defined as follows:

1. Generate initial level 0 (full) backups for 200 databases within 24 hours.
2. Copy virtual full backups of 200 databases to tape within 7 days.
3. Report continuous, real-time Recovery Point Objective (RPO) of less than 5 seconds.
4. Complete 200 concurrent incremental level 1 database backups within 8 hours.
5. Restore 2 databases while the remaining 198 databases are concurrently backing up.

To achieve the goals, an initial level 0 (full) backup to the Recovery Appliance was generated for each protected database. Then, a series of workload generation tests were run to induce database block changes, with a level 1 (incremental) backup taken after each load test. All databases had the same number and size of data files. In addition to SYSTEM, SYSAUX, UNDO, and USERS, there were 29 data files of 14 GB each used to store the workload schema – thus, the size of each database was approximately 450 GB.

For information about the Recovery Appliance's incremental-forever strategy and virtual full backups, refer to the Zero Data Loss Recovery Appliance white paper (http://www.oracle.com/technetwork/database/availability/recovery-appliance-twp-2297777.pdf).

Test Environment

To simulate a real world scenario, the test environment was set up to include a combination of different hardware and Oracle database versions, as described in this section.

Configuration

The information that follows describes the relevant details of the Recovery Appliance, protected databases, networking, media library, and monitoring interface used for the test runs.

Recovery Appliance

The Recovery Appliance used was an X5 full rack with 2 compute servers and 18 storage servers. The ingest network on each compute server had two 10 Gb/sec Ethernet ports configured with LACP bonding. This configuration allows a total system ingest throughput of up to 40 Gb/sec.

Protected Database Hosting

Table 1 shows the hardware used to host the protected databases, along with the distribution of the databases among the host systems in the test environment. All systems used high performance disks.

TABLE 1. DISTRIBUTION OF PROTECTED DATABASES

Host	Hardware	Database Version	Number of Databases
1	Exadata X3-2 Full Rack	11.2.0.4	64 (8 per node)
2	Exadata X2-2 Half Rack	11.2.0.4	32 (8 per node)
3	Exadata X2-2 Half Rack	11.2.0.4	32 (8 per node)
4	Exadata X2-2 Half Rack	11.2.0.4	32 (8 per node)
5	X4800-M2 + ZFS Storage	11.1.0.7	20
6	X4800-M2 + ZFS Storage	10.2.0.5	20
TOTAL			200

Protected Database Network

Each protected database host used a bonded 10 Gb/sec backup interface.

Tape Libraries

The tape libraries were comprised of two StorageTek SL150 systems with two LTO6 drives in each, connected to the Recovery Appliance using Fibre Channel.

Monitoring Interface

Oracle Enterprise Manager 12c (12.1.0.4) was used to monitor the test system.

Architecture

Figure 1 shows how the various components of the test environment were configured.

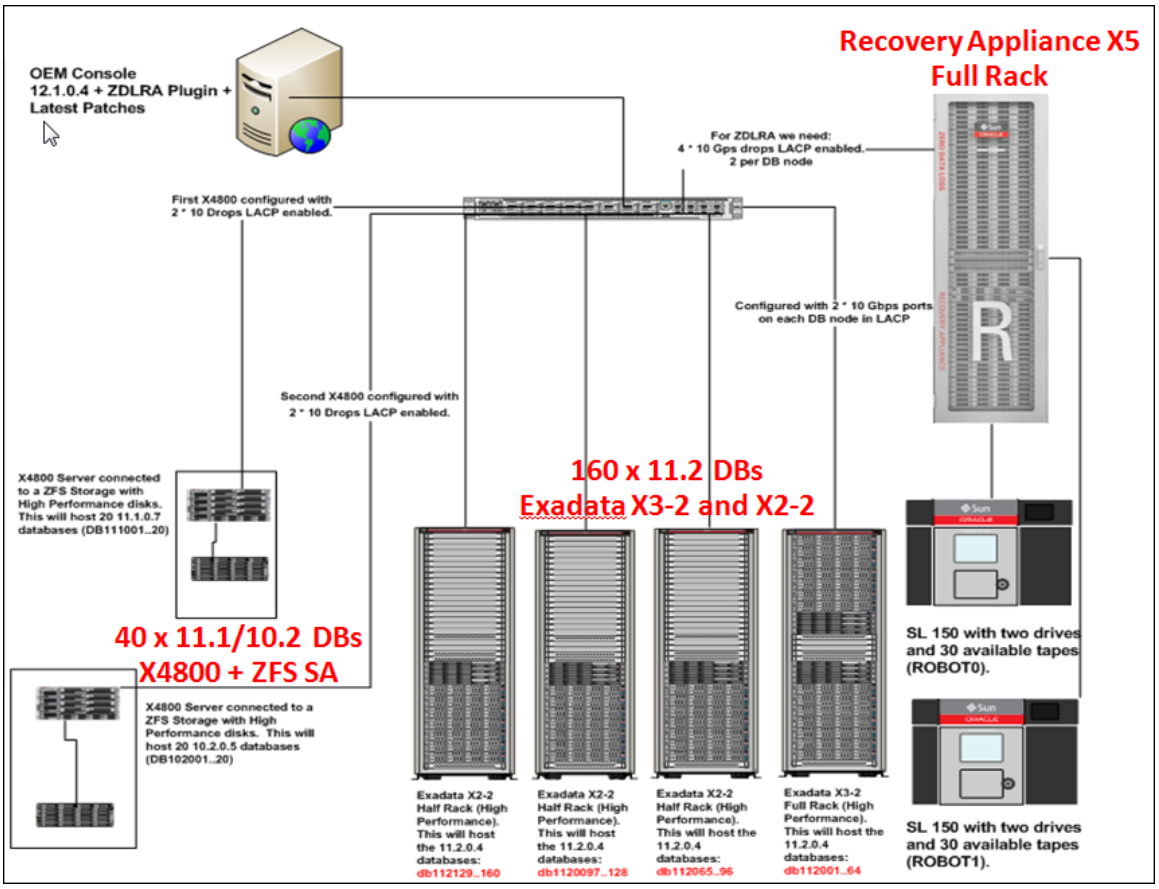

Figure 1: Test Environment Architecture

Tests Performed

This section describes each test, stating the requirements and providing test execution details and results. Most of the supporting figures were captured from Oracle Enterprise Manager 12c with the Recovery Appliance plugin, Oracle Business Intelligence (BI) Publisher out-of-box reports, or Oracle's system monitoring output—tools that are all readily available in Oracle Enterprise Manager 12c Cloud Control. Other figures are of graphs that were generated from OS data collected by using sar, iostat and vmstat system utilities.

Test Case 1: Concurrent Level 0 Backups of 200 Databases

The requirement for this test was to complete an initial level 0 backup for all 200 protected databases within 24 hours.

Results

Passed: All level 0 backups and associated RMAN operations completed in 6 hours and 17 minutes—nearly 4 times faster than the stated 24-hour requirement. The backup rate was 14.7 TB/hr (4.2 GB/sec).

Test Details

While the system was generating concurrent level 0 backups for all 200 protected databases, the throughput and index backup (virtual full creation) activity were monitored.

Figure 2 shows the overlap of the backup operations, with level 0 backups beginning at 16:37 and completing at 22:54, and backup indexing beginning at 17:30 and completing at 00:17.

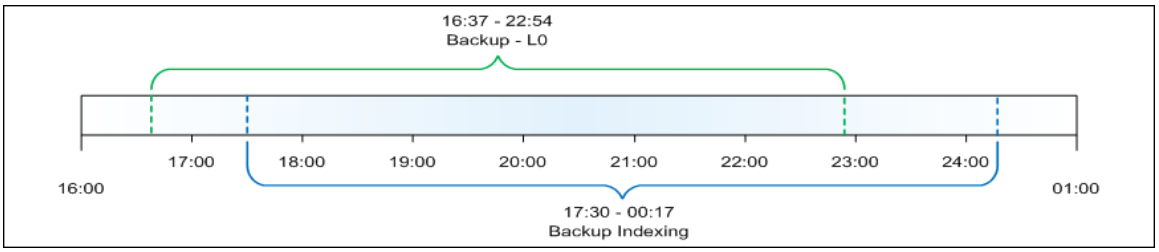

Figure 2: Level 0 Backups and Backup Indexing

Figure 3 shows that during the level 0 backup operations, the Recovery Appliance ingested more than 90 TB of data.

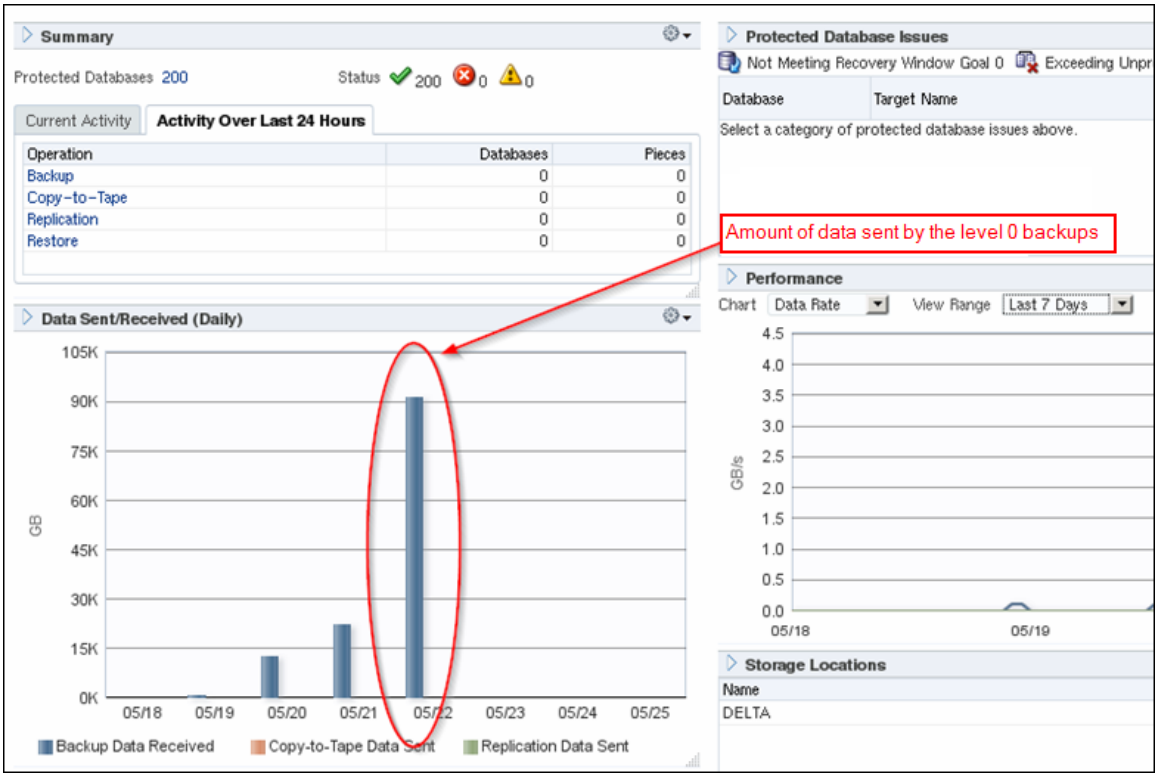

Figure 3: Data Ingestion for Level 0 Backups

Figure 4 shows that the sustained rate of ingestion was approximately 4 GB/sec, the maximum combined rate obtainable based on the available network bandwidth.

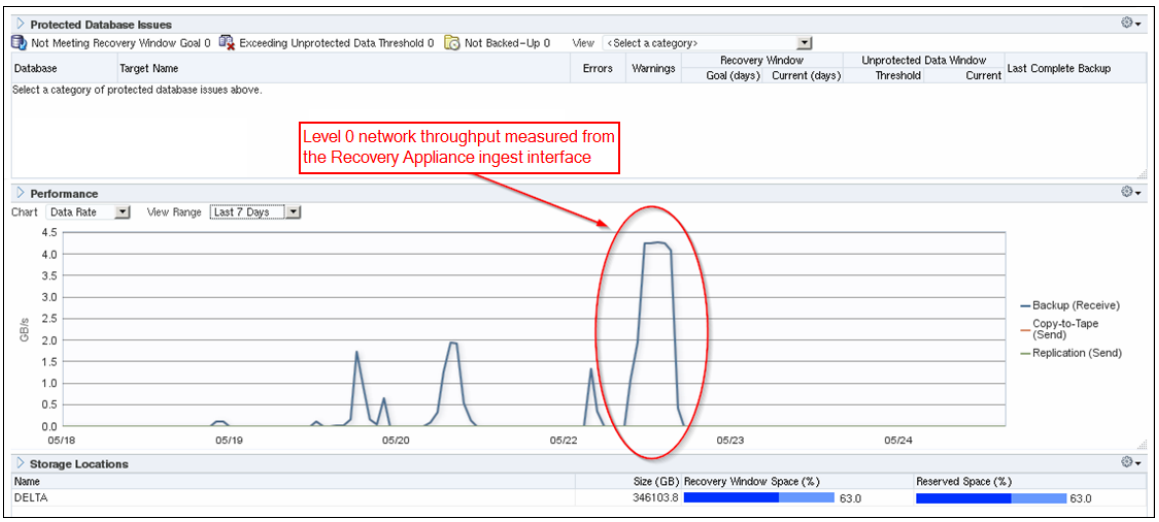

Figure 4: Network Throughput of Level 0 Backups

Figure 5 and Figure 6 show the network throughput peaking at 4 GB/sec and the aggregate CPU utilization at 40% during the initial ingestion of the backups. Note that out of the aggregate, a minimal 10% system CPU utilization (indicated by the gray line) corresponds to backup processing and validation activities.

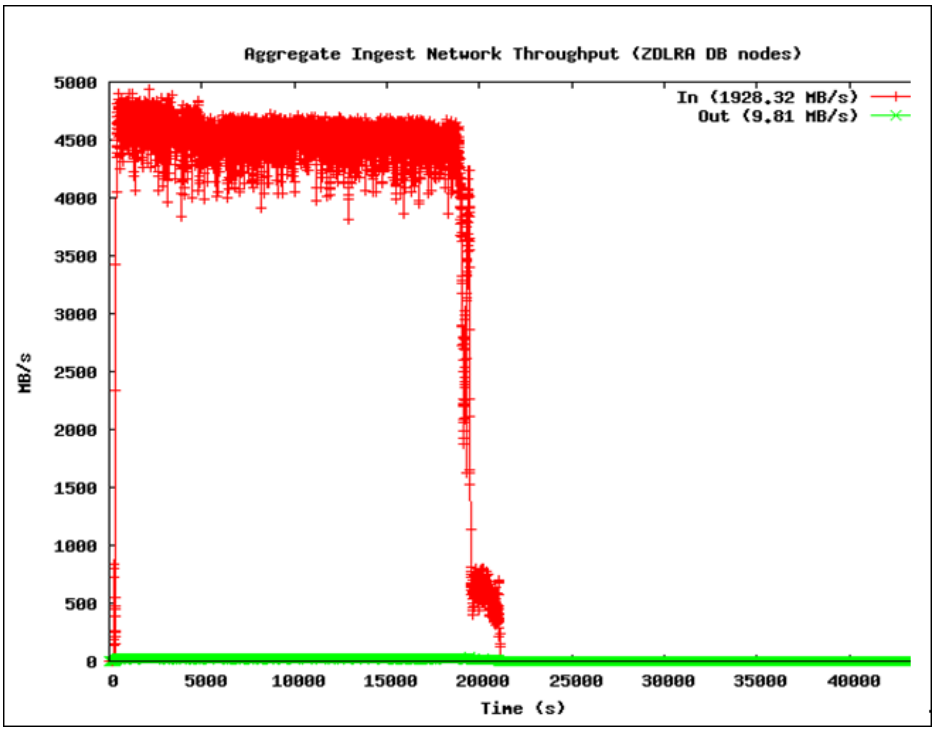

Figure 5: Aggregate Ingest Network Throughput for Test Case 1

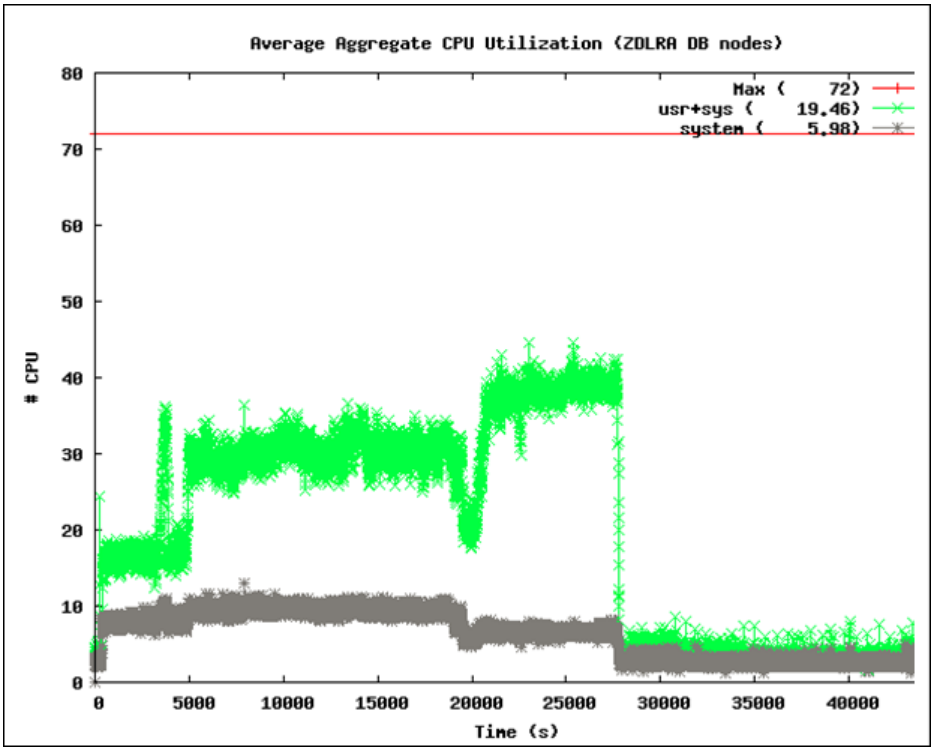

Figure 6: Average Aggregate CPU Utilization for Test Case 1

Test Case 2: Full Backups Copied to Tape for the 200 Databases

The requirement for this test was to complete a full backup to tape for all of the 200 protected databases within 7 days.

Results

Passed: All backup operations completed in 2 days and 3 hours—more than 3 times faster than the stated 7-day requirement.

Test Details

After the level 0 backups were taken in test case 1, a workload generation script was executed. Then, level 1 backups of all the databases were taken and virtual full backups were verified to be completed. Finally, copy-to-tape jobs for these backups were created, scheduled, and executed using four tape drives (two per tape library).

There were a total of 6960 tape backup tasks to be executed. The operations began on 05/27/2015 at 14:06 PDT and completed on 05/29/2015 at 17:33 PDT (approximately two days later). The average number of tasks executed per hour was 258 and the average throughput was 500 MB/sec (125 MB/sec/drive).[1] About 80 TB of data were copied to tape, as shown in Figure 7.

1 This test used only four tape drives. Increasing the number of drives would increase throughput.

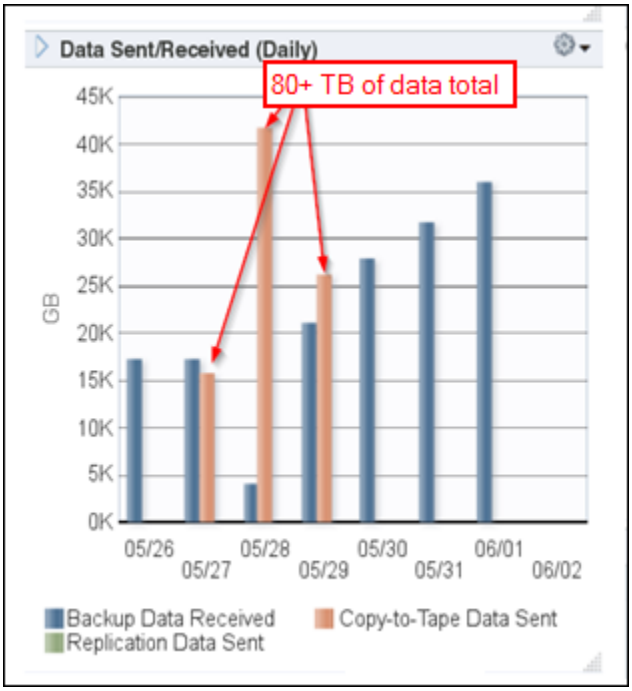

Figure 7: Copy-to-Tape Volume

Tape backup operations work in the background assembling physical full backups from virtual full backups and writing those physical full backups to tape. Tape backups run concurrently while the Recovery Appliance ingests backups and redo. Minimal CPU and I/O resources are consumed.

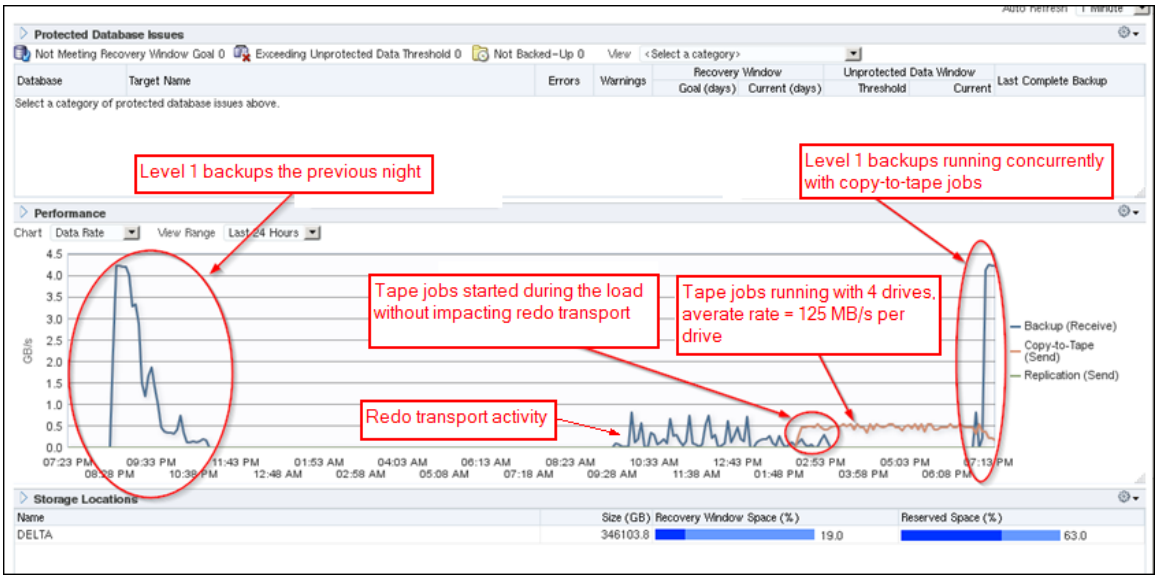

Figure 8: Performance of Tape Backups with Concurrent Level 1 Backups Running

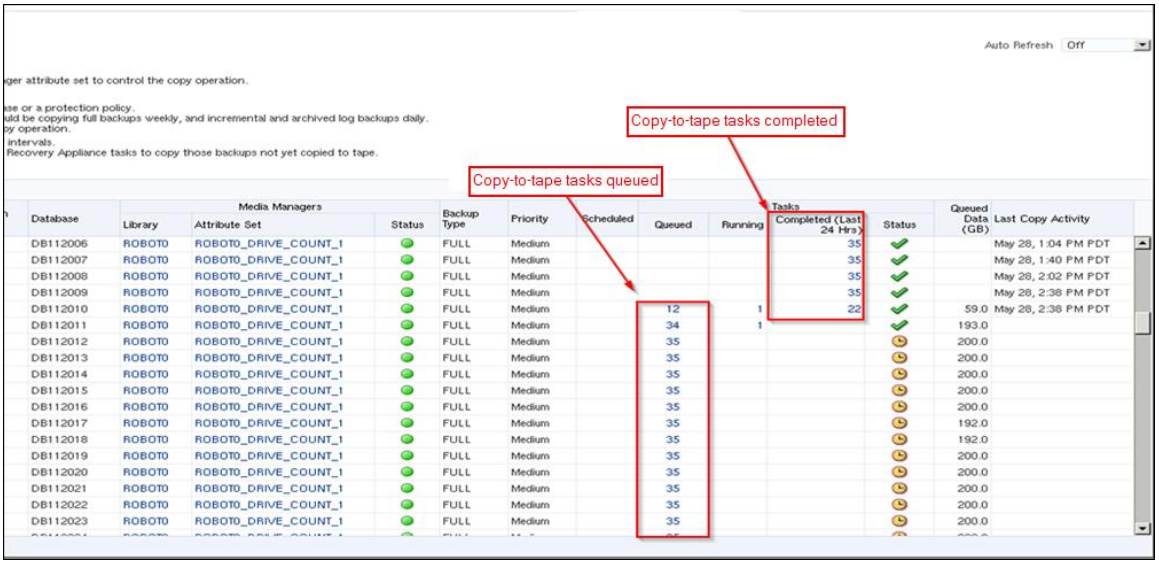

Figure 9: Tape Backup Tasks Queued and Completed

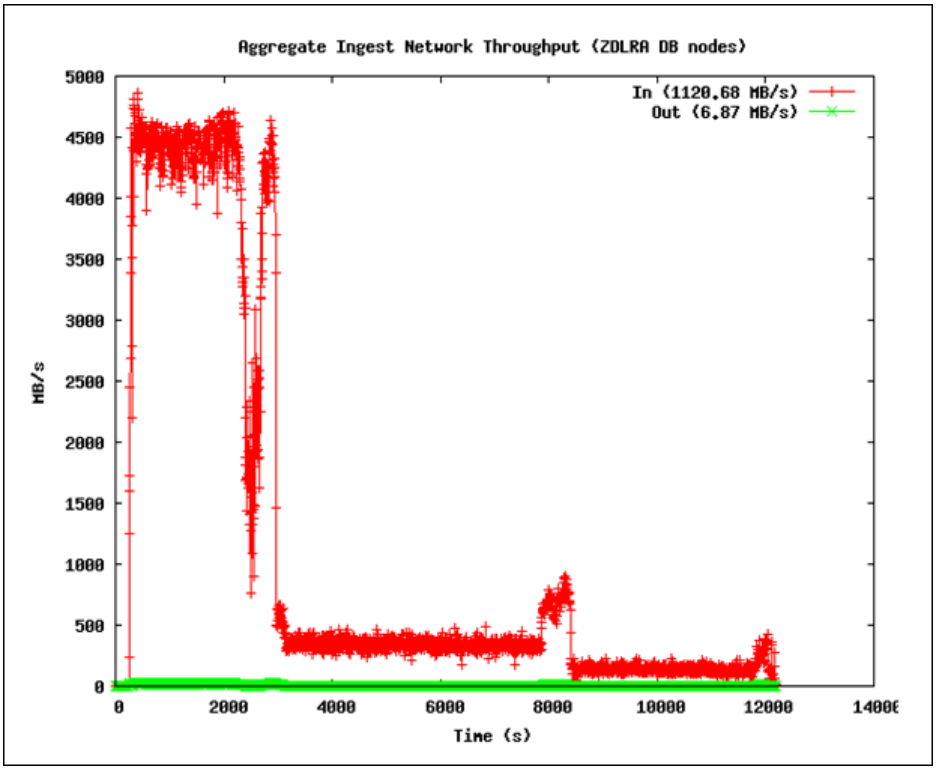

Figure 10: Aggregate Ingest Network Throughput for Test Case 2

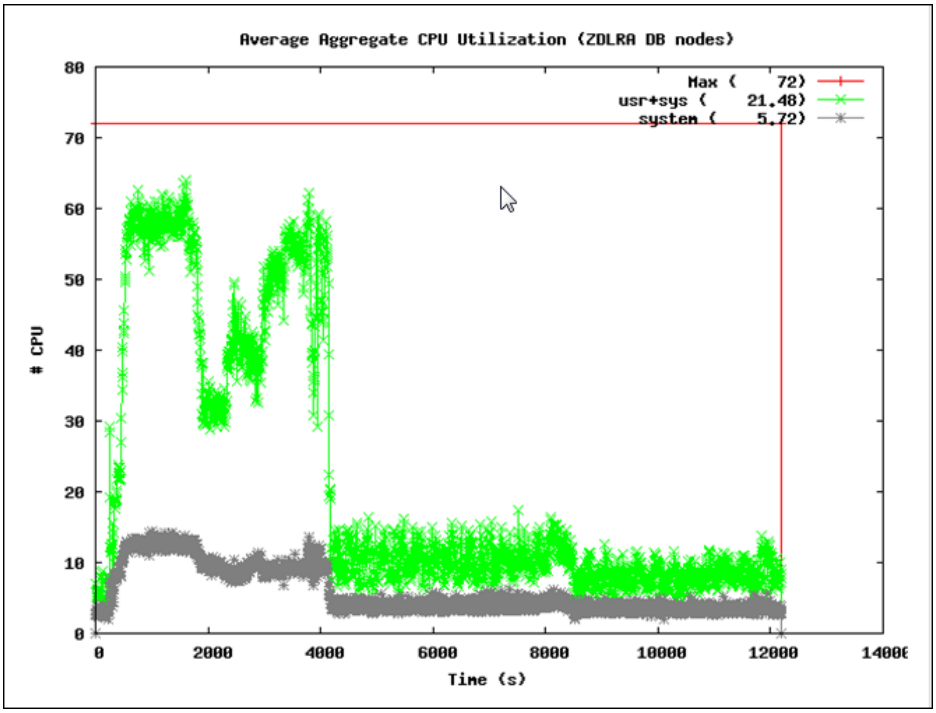

Figure 11: Average Aggregate CPU Utilization for Test Case 2

Figure 12: Aggregated Hourly Copy-to-Tape Data for the Protected Databases

Test Case 3: Maintain a Continuous RPO of Less than 5 Seconds for 160 Databases

The requirement for this test was to confirm that Recovery Appliance can achieve continuous minimal Recovery Point Objectives for a large number of databases.

The optional feature of Recovery Appliance known as "real-time redo transport" allows continuous transfer of redo changes to the appliance from a protected database to protect ongoing transactions, thus maintaining an extremely low RPO (i.e., unprotected data window). For a list of Oracle database releases that support this feature, refer to My Oracle Support Note Doc ID 1995866.1, *Zero Data Loss Recovery Appliance Features Available per Oracle Database Release*.

The 160 Oracle 11.2.0.4 protected databases in the test environment that support this feature were configured with real-time redo transport, and the workload script was run on all of the databases.

Results

Passed: Throughout the duration of the workload, all 160 databases reported an unprotected data window of less than 1 second. This RPO is significantly lower than the RPO of traditional backup solutions, which is typically 12 to 24 hours.

Test Details

The test monitoring tools recorded a combined throughput of 300 – 500 MB/sec (approximately 1.5 to 2.5 MB/sec per database) for redo transport for all the protected databases and an unprotected data window of “0” (indicating zero data loss) during the test run.[2]

Figure 13 shows simultaneous workloads initiated with 160 databases running with real-time redo transport to the Recovery Appliance. The Recovery Appliance ingests the redo with 0 lag time.

2 In this test, the redo transport lag was zero or near zero; however, depending on your application and your network and system resources, redo transport lag may vary per database and environment.

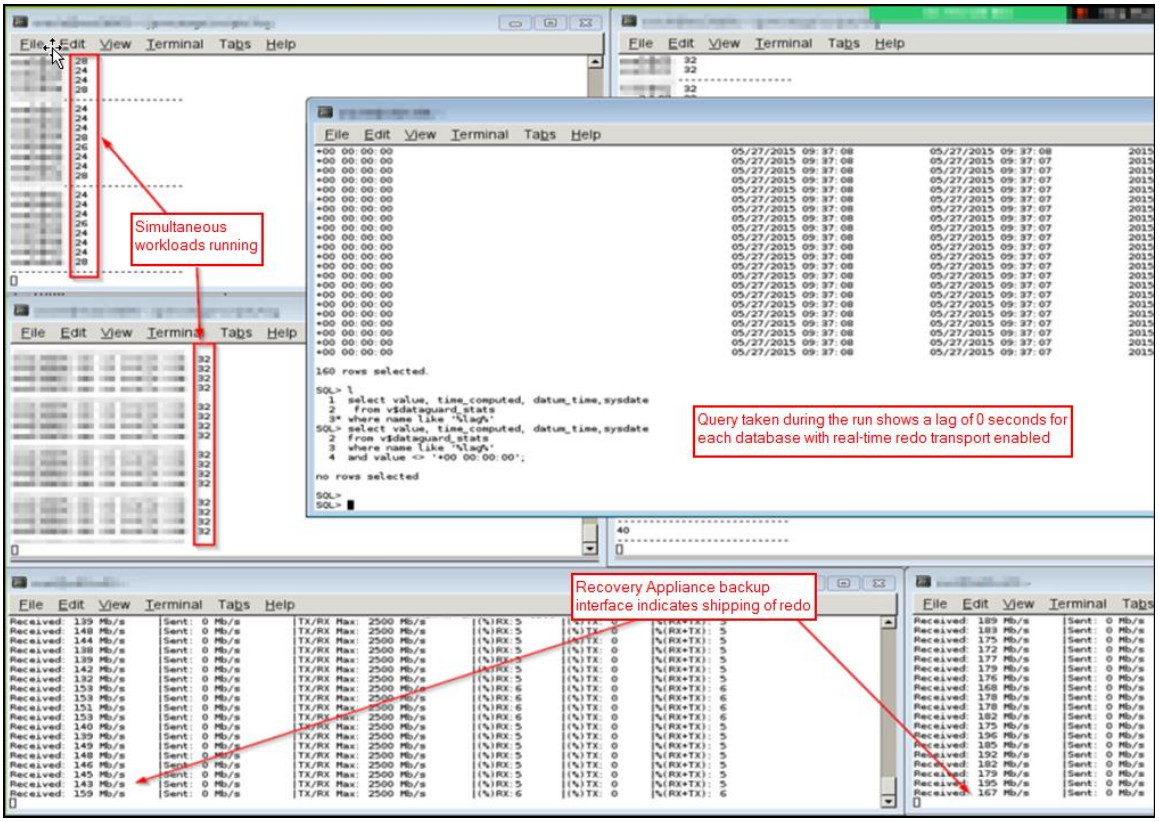

Figure 13: Query Showing 0 Lag for All Databases with Real-Time Redo Transport Enabled

Figure 14 shows that the protected databases with real-time redo transport enabled all have less than 1 second of potential data loss.

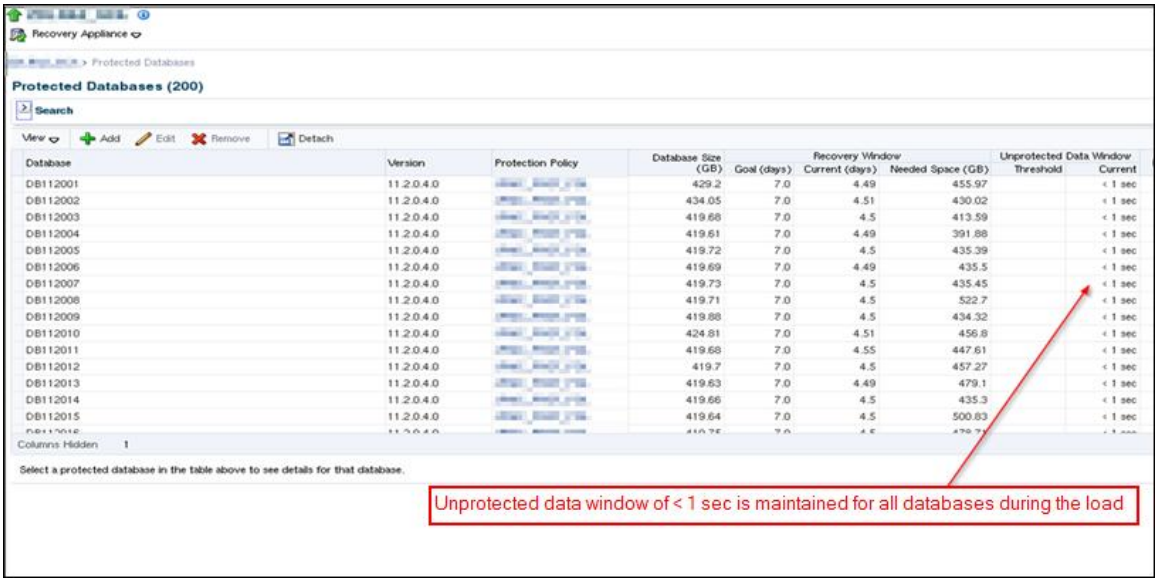

Figure 14: Oracle Enterprise Manager Shows All Protected Databases Maintaining an Unprotected Data Window of Less than 1 Second

Test Case 4: Incremental Level 1 Backups of the 200 Databases

The requirement for this test was to complete all the incremental level 1 backups for all 200 databases within 8 hours.

Results

Passed: All incremental backups were ingested by the Recovery Appliance within 2.5 hours—more than 3 times faster than the stated 8-hour requirement. The virtual full backup rate achieved was 36 TB/hr. This value represents the effective rate to create a virtual full by just performing an incremental backup, i.e. (200 databases x 450 GB per database) / 2.5 hours incremental backup time.

Test Details

An initial level 0 backup was taken on all the databases, followed by the execution of a workload script that generated random block changes of approximately 12% of each database. An incremental level 1 backup was then taken concurrently on all 200 protected databases.

Figure 15 shows that all incremental level 1 backups completed in 2.5 hours, including all index backup (virtual full creation) tasks.

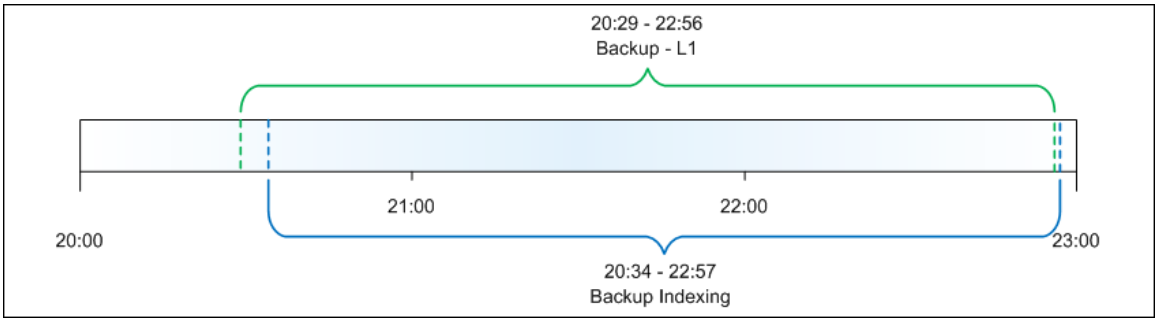

Figure 15: Level 1 Backups and Backup Indexing

Figure 16 shows that as the level 1 backups for the 200 databases started simultaneously, the initial ingest rate reached a maximum of approximately 4 GB/sec quickly, then decreased over time.

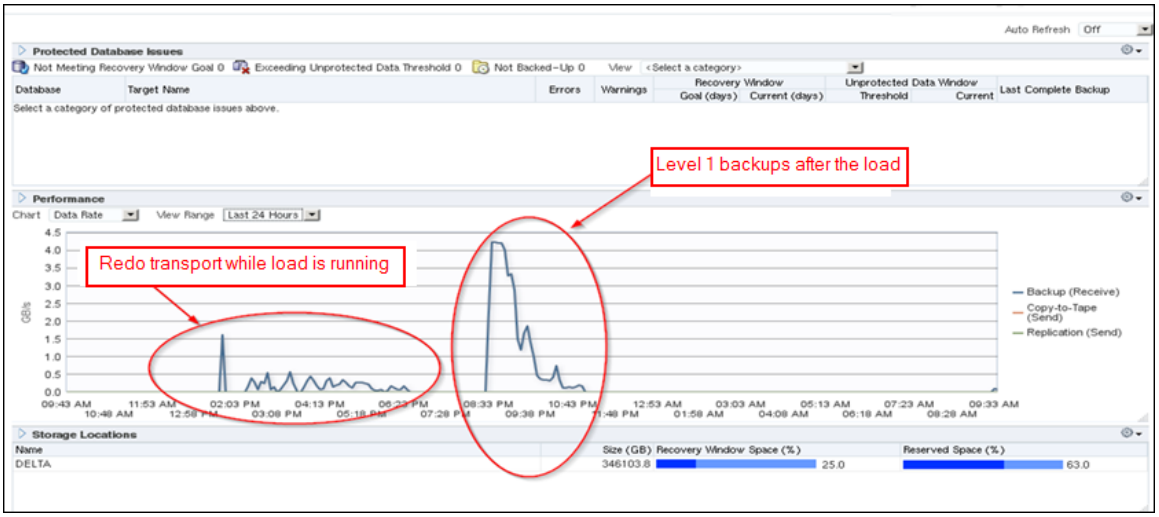

Figure 16: Performance of Level 1 Backups Running Concurrently for 200 Databases

While new level 1 backups are ingested, they are also validated and indexed so that new complete virtual backups for each database can be created and ready for restore or tape backup operations. With all these concurrent operations, the CPU peaked briefly at 70% but was consistently under 60% as shown in Figure 18. Recovery Appliance has internal tasks that manage these operations effectively—ensuring that new tasks such as indexing, purging, validation, and cleanup are intelligently scheduled—so that the system remains balanced with respect to resource usage.

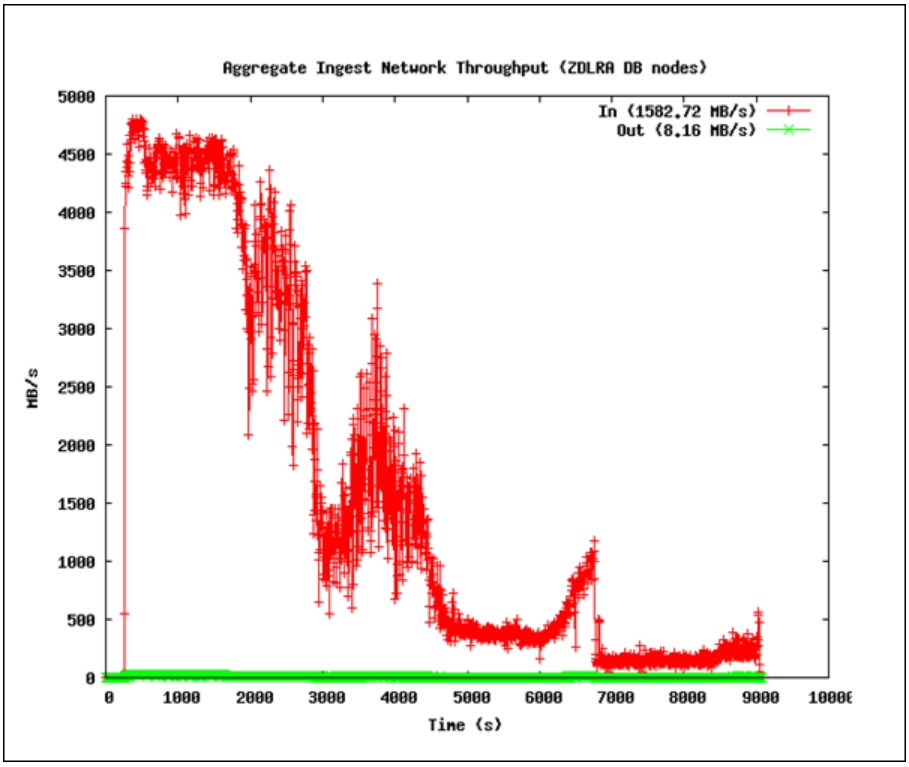

Figure 17: Aggregate Ingest Network Throughput for Test Case 4

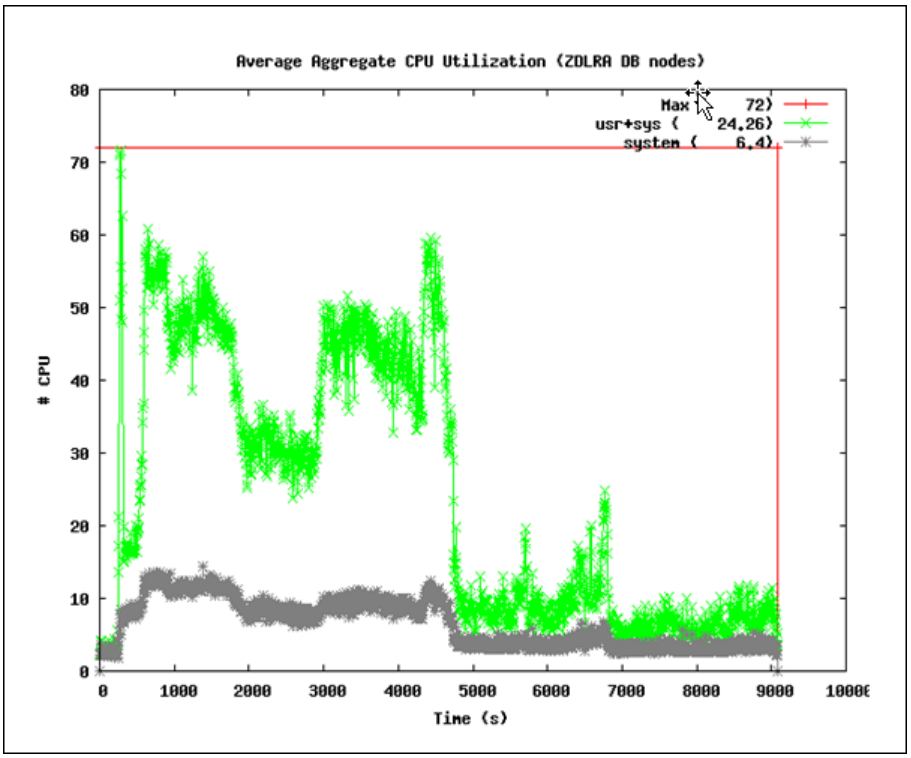

Figure 18: Average Aggregate CPU Utilization for Test Case 4

Test Case 5: Restore 2 Databases While Processing Incremental Backups of 198 Databases

The requirement for this test was to restore 2 databases while level 1 backups are running for the other 198 databases, and all of the operations must complete within 8 hours. While the level 1 backups are running, the 2 databases must be restored without impacting the 8-hour backup window requirement of test case 4.

Results

Passed: All incremental backups and the two restore operations completed within 2 hours—a full 4 times faster than the stated 8-hour requirement. The restore rate was 225 GB/hr.[3]

Test Details

For this test, one Oracle 11.2.0.4 database and one Oracle 11.1.0.7 database were selected to be restored. Level 1 backups for the remaining 198 databases were started simultaneously, and 12 minutes later, restore operations were started for the two selected databases. Figure 19 shows how the concurrent level 1 backups ran and completed successfully within 2 hours while the two restore operations also ran and completed within the same time frame.

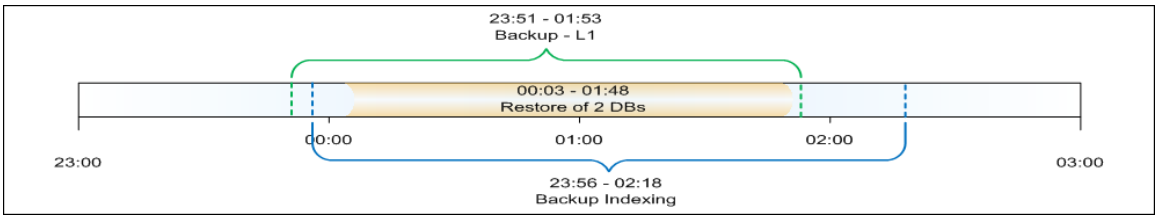

Figure 19: Level 1 Backups with Concurrent Restore of 2 Databases

3 Concurrent backups use most of the bandwidth, limiting the bandwidth for restore operations. Restore operations with no concurrent backup workload can achieve rates of up to 14 TB/hr.

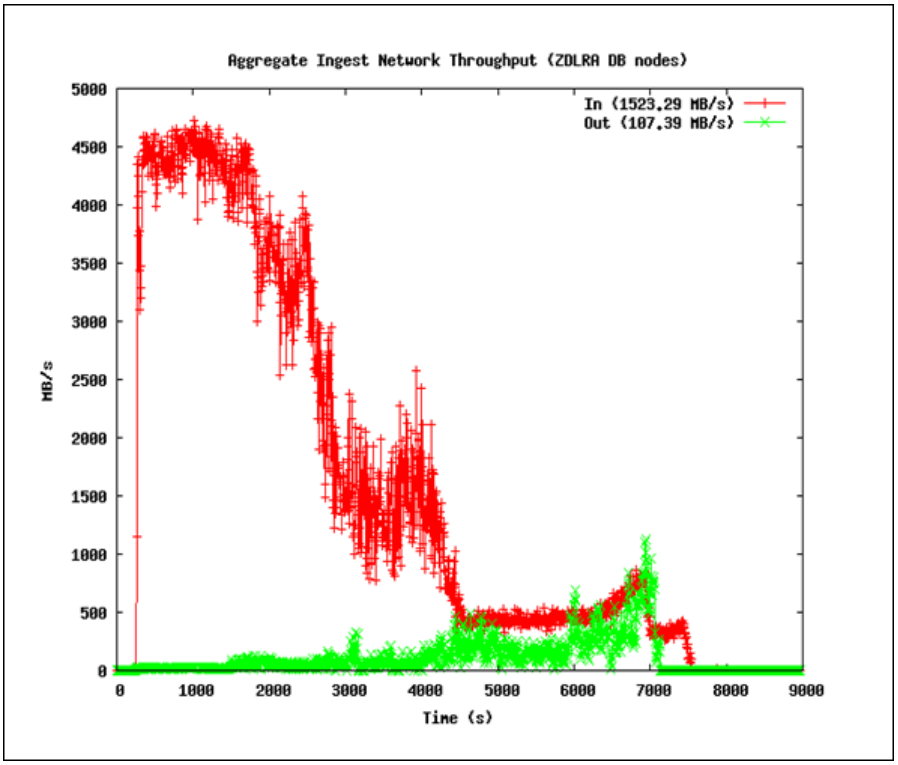

Figure 20: Aggregate Ingest Network Throughput for Test Case 5

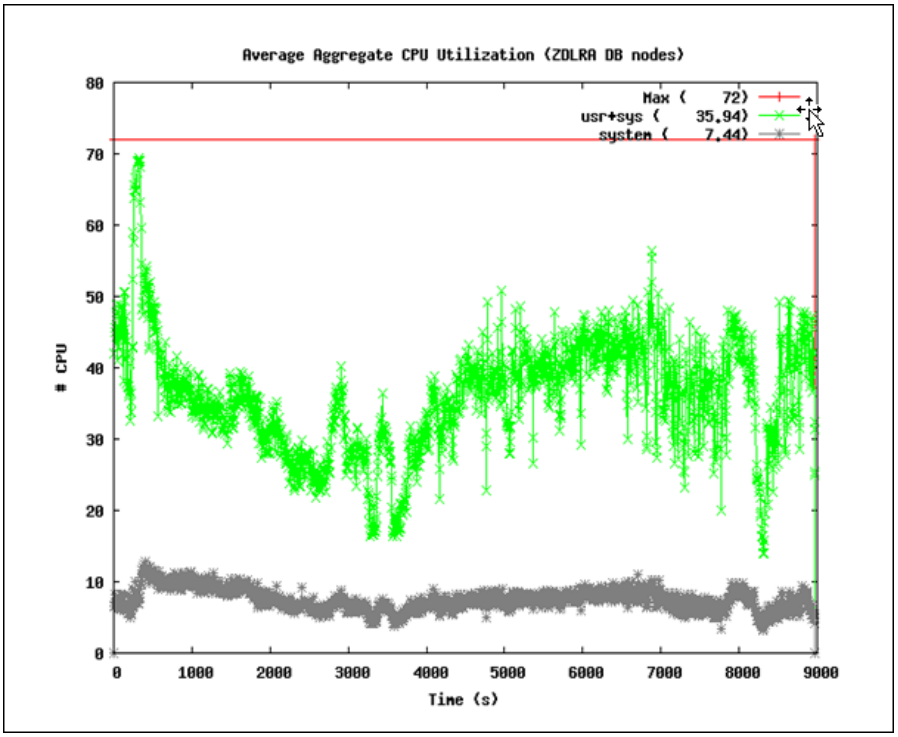

Figure 21: Average Aggregate CPU Utilization for Test Case 5

Recovery Appliance Resource Utilization During Testing

This section provides additional information about CPU, memory, and space usage while all five tests were conducted.

Figure 22 and Figure 23 show the CPU utilization on node 1 and node 2 for the entire duration of testing.

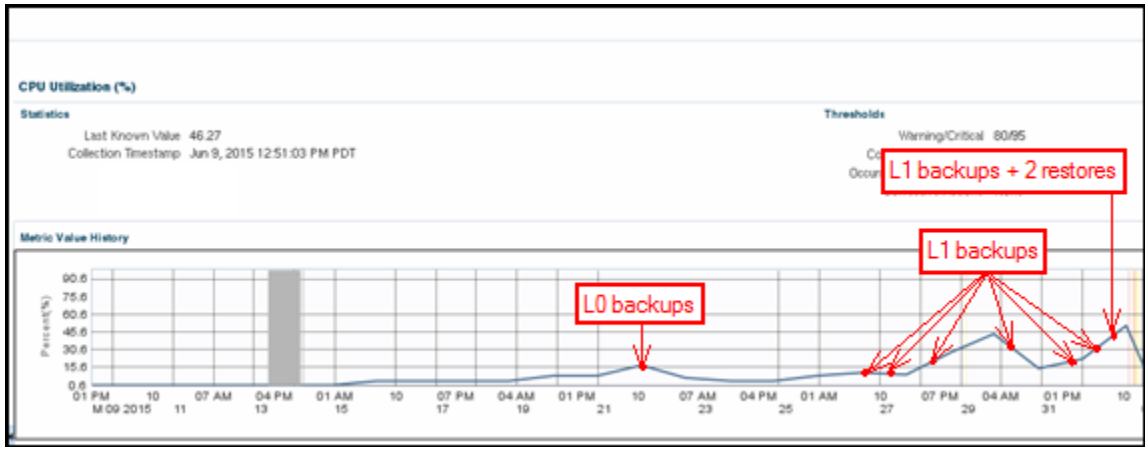

Figure 22: Node 1 CPU Utilization

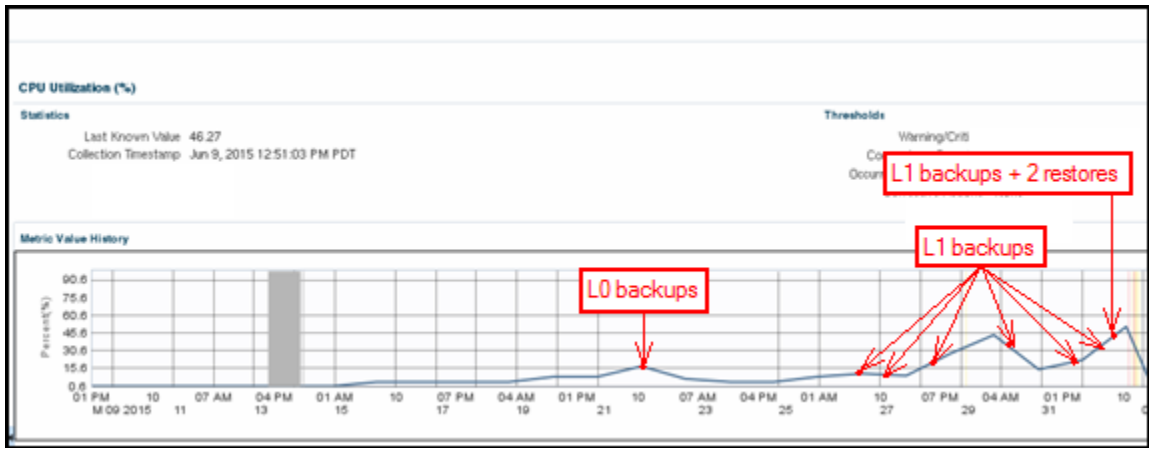

Figure 23: Node 2 CPU Utilization

Figure 24 and Figure 25 show the memory utilization on node 1 and node 2 for the entire duration of testing.

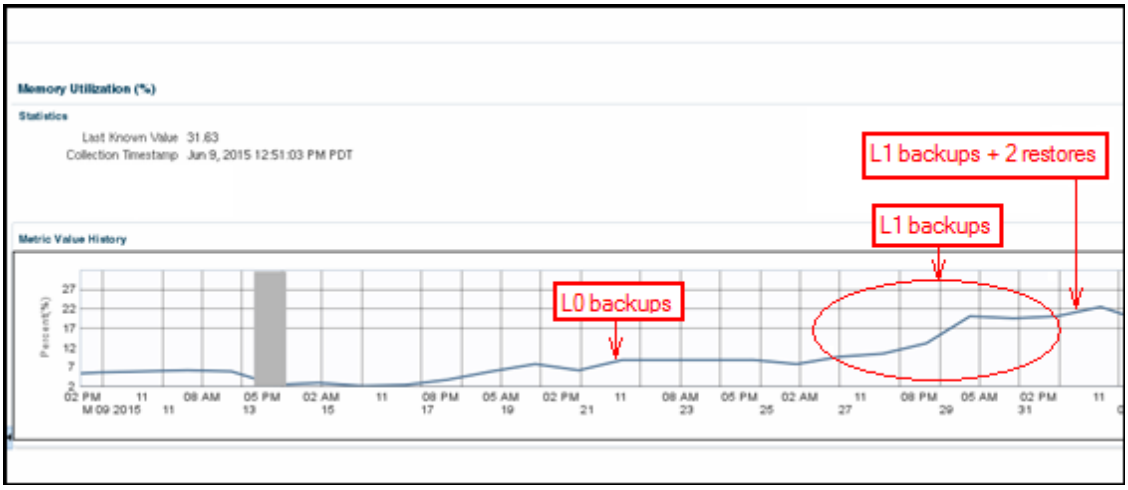

Figure 24: Node 1 Memory Utilization

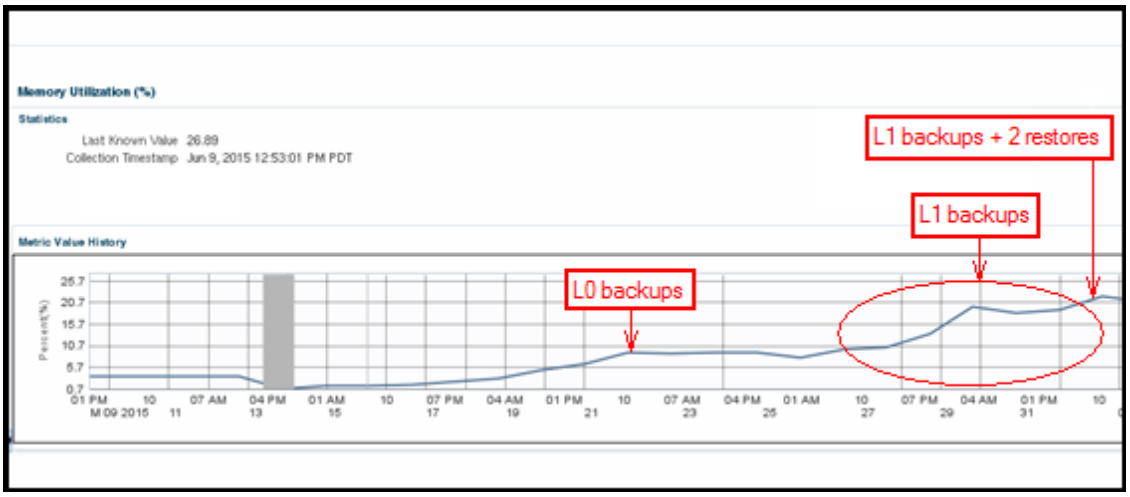

Figure 25: Node 2 Memory Utilization

Figure 26 shows the compression savings achieved on the initial level 0 backup and individual level 1 backups. The higher ratio of compression savings in the level 1 backups is due to a greater percentage of compressible data within the incremental blocks resulting from various system activities that changed blocks associated with undo, system, and sysaux tablespaces.

At the end of eight incremental level 1 backups, a 10:1 effective deduplication ratio was achieved as compared to traditional full backups.

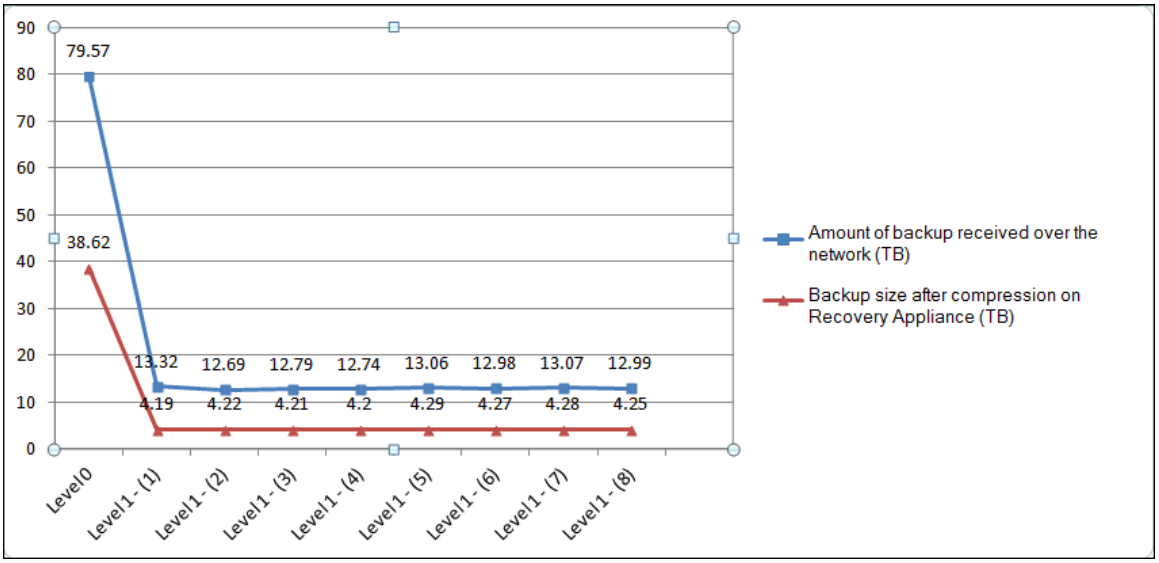

Figure 26: Volume of Backups Received and Backup Size After Compression

Conclusion

This paper demonstrated how Recovery Appliance addressed critical backup and recovery challenges of a large Oracle enterprise customer, and exceeded all performance goals they set.

The proof of concept results showed:

- 200 level 0 database backups completed in 6.3 hours, as compared to the goal of 24 hours.
- Virtual full backup of 200 databases to tape completed in 2 days, as compared to the goal of 7 days.
- Real-time recovery point objectives reported continuously as less than 1 second, as compared to the goal of less than 5 seconds.
- 200 level 1 database backups completed in 2.5 hours, as compared to the goal of 8 hours.
- 2 databases restored in 2 hours, while the remaining 198 databases were concurrently backed up in 2.5 hours.

All results were achieved with no special tuning or configuration of the Recovery Appliance. Your results may differ depending on aspects of your environment such as your network infrastructure between the protected databases and the Recovery Appliance.

Based on these results, Recovery Appliance now paves the way for the customer to:

- Replace the costly local storage used today, providing much more efficient storage utilization for backups, while delivering less than 1 second recovery point objectives.
- Leverage Oracle-integrated and one-step restore capabilities from disk and tape, lowering overall RTO and eliminating the need for multiple groups and steps involved in time-critical restore operation.
- Standardize backup management and monitoring across the enterprise.

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