Maximize the Performance Benefit from Enterprise Flash Drives by Sharing through Virtual Provisioning in EMC CLARiiON CX4

Abstract

Enterprise Flash drives (EFDs) can significantly boost different database applications that are throttled by I/O system service latencies. The Virtual Provisioning™ feature in EMC® CLARiiON® systems simplifies the storage administration challenges of allowing these applications to effectively share a fixed set of EFDs, optimizing the utilization of one of the most powerful but expensive set of enterprise resources.

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Executive summary

The introduction of the enterprise Flash drive (EFD) integrated offering in the EMC® CLARiiON® CX4 product has been a major game changer. Critical business applications that used to be throttled by I/O subsystem service latencies are now running with a many-fold service level speedup. EFDs are being adopted very quickly to provide the much needed performance boost that many operations have been looking for without requiring significant application retuning and redesign.

The Virtual Provisioning™ feature added to the CLARiiON CX4 platform at release 28 allows storage resources inside a CX4 storage system to be shared easily by multiple applications in a Virtual Provisioning pool.

By sharing the EFDs through a virtually provisioned storage pool, multiple applications can be sped up by taking advantage of the EFDs, while the enterprise can readily manage, control, monitor, and ensure that the EFDs are delivering the maximum yield to all applications, providing the most performance benefit across the different applications critical to the enterprise’s business. The benefits from the EFD investment will be maximized.

The integrated support for EFDs offers a new storage tier in the CX4 storage systems and radically changes the I/O service latency experienced by typical database applications, such as Online Transaction Processing (OLTP) workloads. Average I/O operations per second against data stored or moved to the EFDs are many times those that can be expected from rotating disk drives. Average service latencies go from many milliseconds to microseconds. By judiciously leveraging the EFDs, existing application services get multifold improvement in total service system throughput. In addition, without rotating parts, EFDs operate at a considerably lower power requirement, needing much less cooling, and allow considerably more data to be packed within each drive, without sacrificing the speed to get access to all the stored data. Hence, not only do EFDs offer performance. They also go a long way in minimizing the total cost of storing all the crucial data assets of the enterprise.

While the use of tier 0 EFDs emphasizes throughput, the Virtual Provisioning feature emphasizes ease of sharing, allowing critical storage resources to be optimally utilized to support the many continually changing and growing storage capacity as well as performance needs by all the different applications essential to the support of the business. By effectively sharing, fewer physical resources would need to be deployed, reducing both the storage resource acquisition and operation cost.

Given the acquisition cost of the EFDs (which is still relatively high in today’s marketplace compared to rotating disk drives), and the significant operational effectiveness boost they can offer, it would be natural to explore the general guiding principles for creating an enterprise deployment model where the EFDs can be readily shared, and fully leveraged.

Introduction

This white paper covers the engineering case study conducted by the EMC CLARiiON engineering team, exploring a representative deployment scenario where multiple database applications are involved. Starting with a test scenario with two concurrent workloads sharing a CX4 storage system with an FC data store, this paper covers the process by which the “hot data set” for each workload was identified. The hot data sets were migrated to a pool of EFDs, thereby resulting in a boost to the operational efficiency for both workloads, while ensuring that the added storage tier investment made for EFDs was fully capitalized.

Audience

IT staff responsible for storage infrastructure investment and effective deployment will gain some helpful hints in planning and configuring CX4 storage systems, which combine the benefits offered by both the tier 0 EFDs and the ease of use and manageability of storage Virtual Provisioning. Application service owners will hopefully gain insight into what is viable within the CX4 storage support infrastructure to help improve service efficiency of their application service.

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Terminology

- **EFD** — Enterprise Flash drive
- **LUN** — Logical Unit Number associated with a storage entity within the CLARiiON system. Throughout this paper, it means a regular LUN, to distinguish from a thin LUN, or TLU (see below for TLU)
- **OLTP** — Online Transaction Processing oriented deployments
- **RAID** — Redundant array of inexpensive disks, offering protection against stored data loss
- **TLU** — Thin LUN; a LUN created out of the “thin storage pool,” that may not physically take up all the space within the physical drives that the LUN is mapped to within the CLARiiON
- **TPOOL** — Thin pool; the usable space offered by grouping a number of drives together under the Virtual Provisioning feature.
- **VP** — Virtual Provisioning; the storage provisioning feature where instead of physically allocating and mapping the space used for a LUN to a specific set of drives, delegating the responsibility to the storage system to map and allocate the space needed from a thin storage provisioning pool when data is written into the LUN

Overview

The advantages of using EFDs to booster database application performance, such as for Oracle- or Microsoft SQL Server-based OLTP workloads, and the methodology and guidelines, have been covered in other EMC CLARiiON white papers 1.

Similarly, the value proposition of leveraging CLARiiON Virtual Provisioning to effectively support and share CLARiiON storage resources is covered in another related white paper 2.

So as not to duplicate what those other papers have already covered, this engineering case study will take a slightly different approach.

For most enterprises with multiple deployments, new options such as EFDs and Virtual Provisioning often trigger initiatives to re-examine current business operations, to look for possibilities of taking advantages of the new features to improve operational effectiveness and overall productivity.

For the current case study, we will start with a model of a business deployment that involves two existing OLTP database services, one based on Oracle running on a Linux OS, and another with SQL Server running on Windows, with their respective data store housed within the same CX4 storage system.

An operational efficiency improvement project is undertaken to explore how investing and upgrading the existing storage infrastructure with a “reasonable” increment of EFDs, and properly sharing the tier 0 storage addition, can result in a quantifiable benefit to both applications.

As EFDs are still relatively costly (compared to rotating disk drive storage), the focus is on being able to achieve and demonstrate a “boost” in the overall performance when both applications are running concurrently, with each application sharing part of the EFDs added. A selected portion of each database will be targeted for being relocated to the high performance tier 0 EFDs. And the EFDs will be shared as a thin pool to ease the effort of accommodating the migration of the different “hot tables” from both databases, as well as handling growth for both databases.

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1 *Leveraging EMC CLARiiON CX4 with Enterprise Flash Drives for Oracle Database Deployments* and *Implementing EMC CLARiiON CX4 with Enterprise Flash Drives for Microsoft SQL Server 2000 Databases*  
2 *EMC CLARiiON Virtual Provisioning*  
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Engineering case study
The following sections cover the scenarios tested

Baseline deployment description
The baseline deployment scenario is an operational environment including two OLTP test workloads, each running against a different database.

The first database is logically about 1 TB, supported by an Oracle 11g database instance running on an Oracle Enterprise Linux 5.2 server. The second database is a Microsoft SQL Server database, running on SQL Server 2008, under Windows 2008, with about 600 GB of data.

The two databases statically share their data on a set of 30 FC drives, 300 GB/drive, at 15k rpm. Each database has its data evenly distributed among six LUNs. Each LUN is formed out of five of the 30 drives organized as 4+1 RAID 5.

In addition, 10 other physical drives, organized into two 4+1R5 groups, are used exclusively for transaction logs and temporary space.

Figure 1. Baseline deployment configuration
For the typical deployment, both the Oracle OLTP test workload (a TPC-C like simulated workload) and the SQL Server workload (another TPC-E like workload) are run concurrently.

In as much as both workloads are OLTP-oriented the actual application transaction profiles and logic are different. Through some comparative analysis of the server resources and storage I/O characterization, a normalization factor was experimentally established. Roughly estimated, each SQL Server qualified transaction completed with the test workload was found to require about 1.73 times the work and resources compared to a qualified transaction from the Oracle test workload. To simplify comparison for the “effective throughput of the deployment,” the measured transaction rate achieved by the SQL Server database test workload will be normalized and added to the Oracle database workload throughput rate measured. This allows us to compare the effect of introducing the EFD pool into the deployment more directly.

Baseline workload performance measurements

Table 1 summarizes the baseline transaction peak rate achieved by running the test workloads. Each workload was run exclusively with the other shut down, and then both workloads were run concurrently.

Table 1. Baseline transaction peak rates

<table>
<thead>
<tr>
<th></th>
<th>Oracle workload only</th>
<th>SQL Server workload only</th>
<th>Both test workload running together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transaction rate</td>
<td>10727</td>
<td>6206</td>
<td>5335/3020</td>
</tr>
<tr>
<td>Normalized rate*</td>
<td>10727</td>
<td>10727</td>
<td>10560</td>
</tr>
</tbody>
</table>

Adding the enterprise Flash drive virtual pool

A new pool of five enterprise Flash drives with 400 GB capacity was introduced into the CX4-480. The pool was organized as 4+1R5, yielding a total usable pool space of roughly 1400+ GB.

From the pool, 12 thin LUNs (TLUs) were created, each logically 250 GB in size.

Six of the TLUs were assigned to be used by the Oracle database instance. A new Oracle 11g ASM group, the EFDDATA group, was created using those six TLUs.

The other six TLUs were LUN masked and added into the storage group and projected up to the Windows host running the SQL Server engine. These were quick formatted as new NTFS file system drives to be added to the SQL Server instance as a target file system for creating new, or moving existing, database files to the EFDs.

Even though the 12 TLUs logically total 3000 GB, when these are coming out of the thin storage pool, only the actual amount of space used for creating new database files in the new ASM group (for the Oracle database) or the new NTFS file systems (for the SQL Server database) is actually allocated.

Leveraging the additional space in the thin pool to boost performance for both workloads

A key advantage of moving the data for any existing deployment from rotating disk drives to EFDs is that if the workload performance has been constrained or limited by storage access latencies, the transition will immediately relieve those constraints, avoiding a lot of redesign to the database schema, storage layouts, and application logic to try to work around the I/O latency issues.

Both Oracle and SQL Server performance tuning guidelines and best practice documents cover how to identify I/O service latency bottlenecks using different performance measuring and monitoring tools. The
methodology and approach of using different tools provided by Oracle and Microsoft for identifying such bottlenecks from actual running deployments, and where EFDs are potentially good targets for, have already been covered in other Virtual Provisioning white papers, and will not be repeated here.

In the white paper *Leveraging EMC CLARiiON CX4 with Enterprise Flash Drives for Oracle Database Deployments*, in the section “Analyzing the Oracle AWR report or Statspack report,” the approach of using the I/O statistics section of AWR reports collected against typical workload operation windows to identify data candidates suitable for EFDs is covered in considerable detail. Primarily, through the AWR I/O statistics, we can identify the Oracle tablespaces with the heaviest I/O, and also the tablespaces that have the highest I/O “object intensity” as defined by Oracle.

Similarly, in the white paper *Implementing EMC CLARiiON CX4 with Enterprise Flash Drives for Microsoft SQL Server 2000 Databases*, in the section “Using SQL Server to identify I/O problems,” the approach of using SP_monitor and fn_virtualfilestats to help with identifying the database files and objects with the heaviest I/O, and frequently, the highest sensitivity to I/O service latencies, is covered in detail.

It is obviously not possible to move all the current data from both Oracle and SQL Server databases, totaling over 1600 GB, to the thin EFD pool from the current 30 FC drives.

However, given that the objective is really only to try to improve the existing deployment of both test workloads by incrementally acquiring and augmenting the current CX4-480 storage unit with a relatively small number of EFDs, it is not necessary to try to target all the data to be moved.

Instead, through the I/O activity statistics analysis process, we identified the key tables that should benefit the most from being moved from their existing FC location to the new location in the EFDs.

**Moving selected tables to the new EFDDATA group for the Oracle database**

In examining the AWR reports for the Oracle test workload, it was decided that the STOCK table for that database, which comprised of about 30 percent of the database raw data size, received over 65 percent of the I/O activities. It was therefore the logical database object candidate to be moved to the new +EFDDATA ASM group that is formed from the six new 250 GB TLUs presented to the Linux host from the CX4-480 thin pool of EFD drives added to the storage system.

First, the six new LUNs were included in the storage group for the Linux host running the Oracle database instance. These were discovered on the Linux host, formatted, and presented to ASM as new disk candidates.

A new ASM disk group +EFDDATA were created from these six new “Linux disk devices.”

The following logical steps were then executed to copy the content of each of the ASM files making up the different STOK tablespaces that the STOCK table was spread across.

1. Make sure the database was mounted/opened running in log archival mode. (Usually, for most production databases, this would be the case.)
2. Log in to RMAN with DBA privileges (e.g., rman target /).
3. Connect into the database with DBA privileges via SQLPLUS (e.g., sqlplus / as sysdba).
4. “ALTER DATABASE DATAFILE ‘+FCDATA/stok_0_0’ offline” (from SQLPLUS session).
5. “COPY DATAFILE ‘+FCDATA/stok_0_0’ to ‘+EFDDATA/stok_0_0’” (from RMAN session).
6. “ALTER DATABASE RENAME DATAFILE ‘+FCDATA/stok_0_0’ to ‘+EFDDATA/stok_0_0’” (from SQLPLUS session).
7. “SWITCH DATAFILE ‘+EFDDATA/stok_0_0’ to COPY” (RMAN session).

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3 *Leveraging EMC CLARiiON CX4 with Enterprise Flash Drives for Oracle Database Deployments* and *Implementing EMC CLARiiON CX4 with Enterprise Flash Drives for Microsoft SQL Server 2000 Databases*

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8. "RECOVER DATAFILE '+EFDDATA/stok_0_0'" (SQLPLUS session)
9. "ALTER DATABASE DATAFILE '+EFDDATA/stok_0_0' online;" (SQLPLUS session)

This sequence first takes the tablespace files identified by the AWR “hot IO tablespaces” offline (one file at a time). Then, through RMAN, each file is copied by Oracle to create a new tablespace file with the same name in the new EFDDATA group. Finally, the database metadata is adjusted to point the tablespace to use the data now moved to the EFDDATA group.

Moving the selected SQL Server table files to the EFDs
The six new TLUs of 250 GB created out of the new thin pool from the five EFDs were added to the storage group and projected up to the Windows host.

From within SQL Server Management Studio, a new SQL filegroup was formed to take advantage of the EFD LUNs. This is accomplished by right-clicking the database of interest and selecting Properties. From within the Properties page, select the Filegroups tab and click Add as shown in the figure.

![Figure 2. Forming a new SQL filegroup](image)

After creating the new filegroup, select the Files tab to add files that reside on the EFD LUNs to be used for storage of data. The SQL Server database engine will optimize the placement of data between the different files of the filegroup.

To move a table to the new filegroup, perform the following steps
1. Expand the Tables section of the database of interest.
2. Scroll to the Indexes section and expand the tree to view existing indexes on the table.
3. Right-click the clustered index and choose properties
4. Select the storage tab that will allow you to select the filegroup you want to use as storage for the clustered index. (Moving the clustered index to the new filegroup effectively moves that particular table to the new storage group as well. If a clustered index does not exist, it may be necessary to create one.)
5. Optionally, move the non-clustered index into the new filegroup as well.

The following figure shows an example of how to select a new filegroup.

![Selecting a filegroup](image)

**Figure 3. Selecting a filegroup**

Alternatively, with T-SQL, one could use `CREATE CLUSTERED INDEX ix_tblname_name ON tblname (name) WITH DROP_EXISTING ON [FG_NEW]`. With SQL Server 2005 and later, the `ALTER TABLE` has a new `MOVE TO` clause that makes it possible to move tables to a new filegroup. Refer to Books Online for specific requirements of the `MOVE TO` clause.

The `TRADE` table from the SQL Server database, identified as residing on the “hot” files via `fn_virtualfilestats`, was moved to the new EFD-based filegroup using SQL Server Management Studio following the procedure mentioned above.
Testing with the revised storage layout

As a result of migrating the “hot table” of each database to the EFD-based storage pool, the EFD pool reflected about 183 GB of space usage due to the TLUs associated with the SQL Server table, and about 340 GB due to the Oracle table. (Approximately 30 percent each of the original databases were moved.)

Combined workload performance after hot table migration

With the “hot IO” tables for both databases migrated over to leverage the space from the EFD pool, the two test workloads, against the Oracle and SQL Server databases, were rerun. The following table summarizes the performance data collected from the runs.
Table 2. Performance data from the Oracle and SQL Server workloads

<table>
<thead>
<tr>
<th></th>
<th>Oracle workload only</th>
<th>SQL Server workload only</th>
<th>Both test workload running together</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transaction rate</td>
<td>16829</td>
<td>8053</td>
<td>9076/5315</td>
</tr>
<tr>
<td>Normalized rate*</td>
<td>16829</td>
<td>13933</td>
<td>18270</td>
</tr>
</tbody>
</table>

The following graphs compared the operating scenarios before and after the hot tables have been migrated to the added EFD thin pool.

![Effective transaction throughput comparison](image)

**Figure 5. Effective transaction throughput comparison**

The combined test workloads, after normalizing the transactions to equivalent business transactions between the Oracle test workload and SQL Server, came to a 73 percent increase in total throughput.

Should the business operation decide to shut down the SQL Server operation and just run the Oracle workload (e.g., to address seasonal peak business requirements), the relative throughput performance ratio with the migration to the EFD would have been 57 percent. If the operation shuts down the Oracle deployment and focuses purely on running the SQL Server workload, the relative throughput would be improved by almost 30 percent.

Besides the effective overall deployment transaction throughput, the average business transaction response times were also captured and compared as follows:
Not surprisingly, with the added EFD pool, both the Oracle and the SQL Server database workloads ran with improved transaction response times when running together. On average, the Oracle transactions ran with a 12 percent transaction service responsiveness improvement, while the SQL Server-based workload improved by 36 percent.
EFD thin pool space utilization

The following two Navisphere® Manager screenshots illustrate the actual space pool usage for the deployment after augmenting the EFD pool.

Figure 7. Oracle and SQL Server thin LUNs from the EFD pool

Figure 8. EFD thin pool properties

As expected, a bit over 550 GB (roughly 30+ percent of the two databases) was moved to the thin 250 GB LUNs on the EFD pool. The physical space consumed is currently about 38 percent of the total pool, but both “hot” tables from Oracle and SQL Server are logically positioned to grow to 1.5 TB each without
further DBA intervention. As long as the storage administrator monitors and manages the free space available in this pool properly, both tables can be grown to their respective allocated size of 1.5 TB each.

**Interpreting the results**

Obviously, a quick path to boosting an existing deployment involving multiple applications is to allocate more resources to each application. When the application performance is heavily dependent upon underlying supporting storage infrastructure, expanding the storage support, especially with the high performance, and “greener” EFDs, would be a logical consideration.

However, by methodically working through analyzing the existing deployment, it is frequently possible to get a significant boost for the total system performance just by judiciously and effectively adding an incremental EFD investment to the existing CLARiiON storage framework. By properly targeting the high I/O intensity database objects to be moved to the EFDs, it is frequently possible to get a satisfactory boost to the overall operation without needing to move everything to a new EFD-based infrastructure.

Furthermore, because of the high performance offered by the EFDs, and the fact that there is no drive seek latency penalty, it is frequently advisable to try to have multiple applications *share* the space in the set of an EFD investment. By effectively sharing, the EFD investment will be maximally utilized. In business situations where business conditions called for running one of the multiple applications exclusively to ensure that a business condition dictated usage “spike” can be met, the pooling approach ensures that the performance benefit offered by all the EFD drives in the pool is *fully* engaged and leveraged as needed to support the spikes as well.

The testing results as shown on the previous graph support the assertions made. As a whole, the operation improves by 73 percent in effective business transaction throughput after the key tables from both databases have been migrated to the EFD pool. Independently, each workload improves running by itself, though the Oracle and SQL Server workloads, because of the difference in the design and implementation, improve to a different degree.

Also, the overall transaction responsiveness improves on average, even though the overall system is working harder and delivering more throughputs.

The use of the Virtual Provisioning feature in combination with the EFDs allows the added powerful resources to be fully shared, easily partitioned and allocated, and logically overprovisioned to be able to readily support growth.

**Conclusion**

The result of this engineering case study reinforces the assertion that sites currently running with multiple critical business application deployments that are under I/O performance pressure (or anticipating pressure due to continual growth) should seriously examine the viability of making an incremental investment to their existing CLARiiON-based storage infrastructure to add in a complement of EFDs. To fully optimize the benefit of the investment and to improve all applications, the EFDs should be organized as a thin storage pool (or pools), so that all the applications can readily and easily share the use of those drives, using exactly what they currently need, but be logically positioned readily for growth.
References

- *Implementing EMC CLARiiON CX4 with Enterprise Flash Drives for Microsoft SQL Server 2000 Databases* white paper
  

- *Leveraging EMC CLARiiON CX4 with Enterprise Flash Drives for Oracle Database Deployments* white paper
  

- *EMC CLARiiON Virtual Provisioning* white paper
  