Abstract

Thin provisioning is a mechanism that is being adopted by many enterprise storage administrators to efficiently manage storage provisioning and storage utilization, by maintaining a common unallocated storage space that is readily available to other applications on an as-needed basis. Enterprise administrators who have been using this mechanism for some time are witnessing a large increase in storage utilization efficiency; meeting their service-level agreements by being able to quickly provision storage for new applications; and more importantly, saving operating costs by upgrading storage in line with business usage.
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1. Introduction
Over the last few years, organizations have seen an enormous increase in the amount of data storage requirements, driven by a pervasive worldwide economy, expanding e-commerce and e-mail, and the digitization of media and information. This growth places tremendous pressure on organizations who are attempting to store, protect, distribute, and derive value from all that data.

Direct-attached disk, while relatively easy to deploy, resulted in islands of unused storage capacity. To solve this problem, storage administrators implemented network-attached storage, which let storage resource pools become shared across the organization. However, because of the pain associated with provisioning storage across organizational lines, many server administrators often request more storage than they plan to use in the near term. The result was that the storage underutilization problem has not really been solved. For example, an application administrator might conservatively require only 200GB of space for the XYZ application, but because he does not have a good estimate of the application’s growth rate over the next year, he decides to be on the safe side and request around 500GB of storage. Once that 500GB of storage has been created and assigned to the application, no other application can use the remaining 300GB of unused space. Underutilized storage negatively impacts resource planning and costs. As a result, storage administrators are still forced to buy new storage systems to meet storage growth, despite having moved to networked storage architecture.

Problems with Existing Storage Provisioning Model
- Administrators overallocate storage, causing space to become trapped and unreclaimable.
- More and more unreclaimable storage space leads to poor storage utilization.
- Decreased storage utilization results in unneeded storage equipment purchases.

This paper is intended to provide details on the alternative NetApp provisioning mechanism, called thin provisioning. The paper will describe methods of implementing thin provisioning to solve the problems of wasted storage space, low storage utilization, and poor return on investment of storage resources.

2. Thin Provisioning Overview
Thin provisioning is a way of presenting more storage space to the hosts connecting to the storage system than has been physically allocated. With thin provisioning, the storage administrator takes an aggregate and creates volumes for different consumers/applications to use, but does not actually allocate any space upfront to those volumes. The space gets allocated only when the host application needs it. The unused aggregate space is available for the existing thinly provisioned volumes to expand or for use in creation of new volumes. Once the aggregate free space declines to a predefined threshold, the storage administrator can attempt to reclaim space from volumes that have obsolete data, can delete volumes that may be no longer in use, or can purchase more storage. By allowing as-needed provisioning and space reclamation, thin provisioning can result in better storage utilization and smaller capital expenditures on storage infrastructure.

Without thin provisioning, when a volume is created for an application, the entire space can be used only by that application, and the unused space in the volume cannot be used by other applications.
• Figure 1) shows this behavior, where the storage administrator takes a single storage system with 2000GB capacity and creates 3 volumes of size 300GB, 500GB, and 400GB, respectively, with 800GB of free space remaining. If the administrator needs to create a new volume for an application that requires 1TB, then he will need to use a different storage system, which may require a large capital investment.

• In Figure 2) for the same scenario with thin provisioning no space is allocated when the volumes are created. The storage administrator can create additional volumes for other applications with the remaining space, without having to purchase another system immediately.

• Figure 3) shows how free space remains available on the aggregate over time, as volumes consume space only when the application writes data into the volume.

This is an example of oversubscription, where volume sizes are shown to end users as greater than the available space and volumes get space allocated as they grow. But oversubscription isn’t the only solution; in some cases the file system or application writes metadata into the allocated storage container to verify container availability or to improve application performance. This will defeat the purpose of thin provisioning. For example, in Oracle® when databases are created, Oracle writes some sort of metadata into the allocated database files, even though the entire space is not used immediately by the application, the space is removed from the storage, making it unavailable to other volumes. For this kind of scenario, the solution should be capable of creating a smaller volume initially and as the application writes the data, the volume should resize and should be reflected in the host file system or the application.

**Thin Provisioning – Benefits**

• Less amount of storage required to enable the business application initially
• Faster, more efficient provisioning process
• Improved storage utilization
• Reduction in capital outlays
• Oversubscription requests can be satisfied as no storage space is allocated upfront

The next section of the document introduces configurations using Data ONTAP® 7G thin provisioning in conjunction with other NetApp storage and application management products.

### 3. NetApp Implementation of Thin Provisioning

For successful implementation of thin provisioning, NetApp provides solution that:

- Allow initial creation of thinly provisioned storage
- Alert the storage administrator when the shared storage pool is almost full
- Provide the ability to manage storage resources when the volume is about to run out of space

The table below maps Data ONTAP 7G features with NetApp products to provide the solutions described above.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Description</th>
<th>NetApp Solution</th>
<th>Supported NetApp products</th>
</tr>
</thead>
</table>
| **Provisioning** | Support creating thin provisioned volumes and LUNs. This could be either  
  a. Provisioning a volume or LUN greater than the available space and space gets allocated as data is written into the volume or LUN  
  b. Provisioning a volume or LUN of smaller size, then resize the volume or LUN as the data is written into it | Volume space guarantees  
LUN space reservation  
Fractional space reservation | SnapDrive® for UNIX®  
SnapDrive for Windows® |
4. NetApp Provisioning Support

With the introduction of Data ONTAP 7G, NetApp supports thin provisioning on both volumes and LUNs.

4.1 Volume-Level Thin Provisioning

- With the volume space guarantee set to None, Data ONTAP allows an administrator to create a large flexible volume (or multiple flexible volumes) which can be greater than the aggregate size. Space only gets allocated to a volume from the aggregate when data is written into the volume.
- An administrator can also, initially, create a smaller size volume with Data ONTAP and later resize the volume to a larger size to accommodate growing data. The volume resize option with Data ONTAP 7G can be configured using FilerView or the storage system CLI.
The `vol autosize` command can also be used with Data ONTAP to automatically increase the volume size once the used space reaches 98% of the total volume size.

These approaches to provisioning and managing storage are extremely efficient by starting with less capacity than will be needed eventually and growing that capacity, manually or automatically, as needed. For example, the administrator could create home directories of size 100GB for 100 users using storage pool of 2TB available, whereas without thin provisioning capabilities the administrator would have required 10TB of storage space to satisfy the requirement.

4.2 Application-Level Thin Provisioning

Data ONTAP 7G supports thin provisioning of LUNs by disabling space reservation, and space gets allocated from the volume as data is written into the LUN. By default, LUNs are created with 100% space reservation, meaning that the total LUN space is allocated from the volume when it is created.

This ability of Data ONTAP 7G adds benefits of satisfying the storage requirements for the application quickly and also no additional investment is made on the storage causing delay in bringing up the service. For example, using this feature the administrator could create 100 100GB LUNs to be used by different applications using storage pool of 2TB available, whereas without thin provisioning capabilities the administrator would have required 10TB of storage space to satisfy the requirement.

4.3 Volume Space Guarantees and LUN Space Reservations in Data ONTAP

Data ONTAP supports three volume guarantee options, as described in the following table.

<table>
<thead>
<tr>
<th>Volume Guarantee Options</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>A volume guarantee of Volume ensures that the aggregate will always have blocks available to honor writes to each and every block in the volume. Basically, the aggregate reserves blocks for the entire size of the volume.</td>
</tr>
<tr>
<td>File</td>
<td>A volume guarantee of File ensures that the aggregate will always have blocks available to honor writes to all the space-reserved files in the volume.</td>
</tr>
<tr>
<td>None</td>
<td>A volume guarantee of None does not ensure any space guarantees from the aggregate. A volume with a guarantee of None can be of any size (even bigger than the aggregate), and even space-reserved files in the volume will not have any space reserved to service their writes.</td>
</tr>
</tbody>
</table>

Space reservation is a feature built into Data ONTAP to guarantee that writes to certain reserved files always get served. This is ensured by reserving certain space upfront while making sure that Snapshot activity will not cause overwrites to these files to fail. Reservations make sure that there is always enough space to service all writes to the protected files. By default, Data ONTAP reserves 100% of space of the LUN size to ensure that the complete LUN can be overwritten. However, this default can be changed to a lower percentage if the data on the LUN is not expected to be completely overwritten.

Space reservations do not ensure that it is possible to create Snapshot copies. Rather, they block the creation of new Snapshot copies when the creation of a new copy would not leave enough space to service future writes to the space-reserved files.
Figures 5 and 6 show how to set up volume thin provisioning and LUN thin provisioning using FilerView.

4.4 SnapDrive Overview
SnapDrive is a storage and data management solution for Windows, Solaris™, HP-UX, AIX, RedHat Linux®, and SUSE Linux. SnapDrive is designed to simplify storage and data management by automating the complex series of provisioning and data protection steps that need to be executed on both storage and host systems. SnapDrive helps the server or the application administrator, by allowing him/her to manage storage space for the application and manage backup and restore operations from the host, removing the dependency on the storage administrator.

Key SnapDrive functionality includes application storage provisioning, consistent data Snapshot copies, and rapid application data recovery from Snapshot copies. SnapDrive complements the native file system and volume manager technology, and integrates with host-side clustering technology to provide high availability services.

Thin Provisioning Support in SnapDrive
SnapDrive does not control how volume space is allocated; it controls space guarantees for LUNs during their creation. By default SnapDrive creates a 100% space reservation; this can be enabled or disabled during the process of LUN creation.

Note: Space guarantees are honored only for online volumes. If you take a volume offline, any committed but unused space for that volume becomes available for other volumes in that aggregate. When you bring that volume back online, if there is not enough available space in the aggregate to fulfill its space guarantees, you must use the force (-f) option to disable the volume’s space guarantees in order to bring the volume back online.

Note: Space guarantees are disabled for FlexClone® volumes.

5. NetApp Storage Management Support
With the number of volumes and Snapshot copies ever increasing, providing adequate tools to intelligently reclaim space helps administrators to manage their systems. Running out of space translates into downtime for users because data cannot be written to storage. Automatic space reclamation helps customers set policies to reclaim space and thus reduce downtime and increase availability.
5.1 Understanding Storage Management Options in Data ONTAP

It is a recommended practice that when you enable NetApp thin provisioning, you also configure storage management policies on the volumes containing the thin provisioned LUNs. The use of these policies aids in providing the thin provisioned LUNs with storage capacity as they require it. The policies include automatic sizing of a volume, automatic Snapshot copy deletion, and LUN fractional reserve.

**Volume auto-grow** is a policy-based space management feature in Data ONTAP 7G that allows a volume to grow in defined increments up to a predefined limit if the volume is nearly full.

**Snapshot auto-delete** is a policy-based space management feature that automatically deletes the oldest Snapshot copies on a volume when that volume is nearly full. You should set the volume option to have the system attempt to grow the volume before deleting Snapshot copies.

**LUN fractional reserve** is a policy that is required when you use NetApp Snapshot copies on volumes containing LUNs. By default, the space reservation is 100%. The fractional reserve percentage allows the user to scale down the overwrite reserve being charged to the volume. This dilutes the space reservation protection on the space-reserved files in the volume (overwrites to space-reserved files or LUNs can fail) but makes more space available in the volume for Snapshot copies and other files or LUNs. Users can choose to lower the fractional reserve from the default setting of 100% because they do not expect to overwrite the entire LUN after a creating a Snapshot copy so they need reserved space based on the rate of change of data.

**Snap reserve** is a percentage of the usable size of the volume set aside to store data belonging to Snapshot copies. It is the space allocated for use by Snapshot copies only. Active file system data (creation of new files or increasing the size of existing files) cannot consume free space in the snap reserve. Any blocks belonging only to Snapshot copies (and not to the active file system) are accounted for in the snap reserve of the volume.

By default, the snap reserve is set to 20% at volume creation. For block access volumes (FCP, iSCSI) it is recommended to set the snap reserve to 0%.

**Expanding Storage**

As your storage needs increase, the administrator might need to expand the storage to hold more data. Data ONTAP 7G provides the right set of tools that enable the administrator to expand NetApp aggregates, Volumes, and LUNs as necessary.

**Note**: After you increase the size of a LUN, you cannot reduce it, except by restoring a Snapshot copy made prior to the expansion of the LUN. Such a restore causes the loss of any data added to the LUN after you expanded it.


One of the most important keys to successful thin provisioning is to carefully track and manage storage capacity. Storage administrators need to monitor the system to ensure that the provision policies they have adopted are stable and would not cause disruption in service.

NetApp Operations Manager monitors and generates reports on all of the NetApp storage systems in an organization. When utilizing NetApp thin provisioning, it is recommended to deploy NetApp Operations Manager and to set up e-mail and pager notifications to the appropriate administrators. With thin provisioned storage, it is very important to monitor the free space available in storage aggregates. Proper notification about the available free space ensures that additional storage can be made available before the aggregate becomes completely full.
NetApp Operations Manager provides a comprehensive list of trigger events that can happen in the storage system and require attention from the storage administrator. For thin provisioning environments, the storage administrator should be interested in how much the aggregate or the volume is growing and should be able to forecast storage requirements by analyzing the trends. For example, if the Aggregate Almost Full notification is configured, the storage administrator would receive a notification when a particular aggregate reaches 80%. This ensures that the storage administrator has enough time to resize the aggregate so that the thinly provisioned volumes can grow without any issues.

Figure 9) Alarm trigger configuration options on aggregate and volumes

With NetApp Operations Manager, storage administrators have more flexibility in defining the threshold levels for different aggregates. For example, the administrator could set Aggregate Nearly Threshold to a lower percentage, for example 75%, for the aggregates that have thinly provisioned volumes, and set it to Default for aggregates where the volume has space guarantees.
**Edit Aggregate Settings**

Set value for comment field 'ownerEmail' to 'oracms@netapp.com' for aggregate DFC-PPE-FILER snapdrive (103).

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner Email</td>
<td></td>
</tr>
</tbody>
</table>

**Edit DFC-PPE-FILER snapdrive Thresholds And Alert Settings**

<table>
<thead>
<tr>
<th>Threshold Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Full Threshold (%)</td>
<td></td>
</tr>
<tr>
<td>Aggregate High Threshold (%)</td>
<td></td>
</tr>
<tr>
<td>Aggregate Low Threshold (%)</td>
<td></td>
</tr>
<tr>
<td>Aggregate Offsite Overcommitted Threshold (%)</td>
<td></td>
</tr>
<tr>
<td>Aggregate Snapshotted Reserve Full Threshold (%)</td>
<td></td>
</tr>
<tr>
<td>Aggregate Snapshotted Reserve Low Threshold (%)</td>
<td></td>
</tr>
</tbody>
</table>

Apply settings to **This Aggregate**

---

**Figure 10** Threshold settings for the aggregate
7. Case Studies

The following examples illustrate which Data ONTAP options are suitable for a particular situation, depending on the application and administrator requirement.

Case 1: Thin Provisioning by Oversubscribing Storage Space
The customer wants consolidated storage for all their applications. One of their major issues is that when users are running out of space, it can take up to few days to provision new or expanded storage for them. The result is that users tend to overrequest the amount of storage they need up front. These and other factors have led to a current very low utilization rate and a large amount of unused space. The customer is becoming aggravated with the storage costs, and also with the real and hidden costs of the cumbersome provisioning processes.

The customer is aiming to drive greater efficiency through the use of value-add software to achieve greater utilization, process improvements, and cost savings in their existing environment.

Business Requirements
• The customer feels that it is not realistic to decide how much of storage is required up front. They require a solution that does not allocate storage up front but that can automatically grow as the storage requirements grow.
• If there is a new application to be implemented, the customer requires that the unused space in the storage system must be used before investing in additional storage systems.
• The customer needs to avoid running out of space and also needs to provision storage quickly.

NetApp Solution Summary
NetApp reviewed the business requirements and proposed to use:
• Data ONTAP thin provisioning capabilities and NetApp Operations Manager to monitor thin provisioned volumes and alert administrators before running out of storage
• SnapDrive in this environment, to give greater control to the application administrator in creating virtual disks and defining backup policies as required by the application

For this scenario, the application administrator requested a 2TB LUN, which he expects the application to use, but the storage administrator doesn’t have enough space in the aggregate. To satisfy the requirement, additional storage systems must be purchased, which would be expensive and would result in delay in implementing the service. Keeping in mind the characteristics and purpose of the application, the administrator feels that it requires only 300GB initially. The application is expected to grow to 2TB in a year, depending on usage. In this case, the storage administrator creates a volume of 500GB and uses SnapDrive to create a LUN of 2TB, which the application administrator requested, with no space allocated up front.

This solution satisfied the application administrator because he got the virtual disk size that he had estimated. It also satisfied the storage administrator, because the existing infrastructure was used to satisfy the business needs.

The storage administrator also deployed NetApp Operations Manager to monitor the aggregate and the volume space to make sure that additional storage is added before the application runs out of its allocated space.

In this case study, only one administrator in the organization is demanding storage, but in a bigger organization the storage administrator may be flooded with requests for storage provisioning. In that case, thin provisioning becomes even more important and cost effective.
When the LUN is created with the Noreserve option, no space is allocated from the volume.

As the data is written into the LUN, the space in the volume is consumed by the LUN.

When the volume space used reaches a threshold Data ONTAP 7G automatically resizes the volume to the configured incremental size.

Configuring Thin Provisioning

Step 1  The storage administrator creates a flexible volume of 500GB with volume guarantee set to volume (default), This allocates only 500GB, which is less than the original requested size.

```
FAS> vol create appabc -s volume apptest 500g
Creation of volume appabc with size 500GB on containing aggregate apptest has completed.
```

Step 2  Change the volume default settings to suit the customer requirements.

- Modify the default fractional reserve settings from 100% to 10%. (In this case, the application is not expected to overwrite data.)

```
FAS>vol options appabc fractional_reservation 10
```

- Following the NetApp SAN best practices, disable Snapshot on the volume and set the snap reserve to 0%.
### Step 3
Configure the volume space management options.
- Enable volume to auto-grow by another 250GB, when the used space becomes 98% of the total space available and to a maximum of 2TB.

```bash
FAS> vol autosize appabc -m 2t -i 250g
```
- Enable Snapshot auto-delete so that older Snapshot copies are automatically deleted to free up space.

```bash
FAS> snap autodelete appabc on
```
- In case of space contention, set the volume to grow first before trying to delete Snapshot copies.

```bash
FAS> vol options appabc try_first auto_grow
```

### Step 4
NetApp recommends using SnapDrive to create and manage storage as well as Snapshot copies of the application data. The storage administrator creates a LUN of the requested size, 500GB, using the SnapDrive CLI and setting the LUN space reservation to OFF.

```bash
LINUX# snapdrive storage create -fs /u01/appabc -lun fas:/vol/appabc/appabclun -lunsize 2t -noreserve
```

- `-noreserve` ensures that the space for the LUN is not reserved up front; space is claimed from the volume only when the data is written to the LUN. In this case, the LUN size is created as the application administrator requested.

### Step 5
NetApp recommends using Operations Manager to monitor free space in the aggregate and alert the storage administrator whenever it reaches the threshold.

Configure NetApp Operations Manager to monitor the aggregate and volume for the following parameters:
- Volume about to get full
- Aggregate about to get full
- Volume full
- Aggregate full
- Volume growth abnormal

For this scenario, create a separate group called “Thin aggr” and add the apptest aggregate as part of this group.

**Figure 15) Aggregate view in NetApp Operations Manager**

#### Setting Up Monitoring Threshold Values
Edit the monitoring threshold of the “Thin aggr” group to suit the requirements, the storage stock, and also the size of the aggregate. For example, if you want to order storage disks to expand the aggregate, set the threshold to a lower value, so that the storage administrator has adequate time to make the purchase.
When all the monitoring tasks are finished, the administrator should feel safe in having a storage environment with better utilization of resources. The storage administrator should still plan to stock a few disks and disk shelves so that she is always equipped. Also, based on the usage trend from the reports, the storage administrator should forecast and plan the storage procurements.

Continuing with the same example, after a few weeks or months, the administrator receives an e-mail that the aggregate is about to get full. With the settings described earlier, the administrator knows that only 25% of space is left in the aggregate, and she can respond by adding a few more disks to the aggregate so that LUN and volume can continue to grow.
NetApp Solution Benefits
After implementing NetApp thin provisioning solutions, the customer in this case study saw the following benefits:

- Significant increase in storage utilization, because the storage pool is shared by various applications.
- Storage provisioning time is greatly reduced, because storage for the application can be created quickly without depending on the actual physical space available.
- Through notifications and configurable threshold values, the storage administrator is able to plan the procurement strategy well in advance and have enough storage for the thin provisioned volumes to grow.
- Storage is procured only when needed, and cost is greatly reduced because storage arrays are not purchased immediately.
- Using the SnapDrive application, the administrator is able to initiate Snapshot copies from the host and manage the copies.
- Snapshot copies created using SnapDrive are application consistent; that is, even if the LUNs used by the application span multiple storage systems or NetApp volumes, SnapDrive freezes all I/O operations to the LUNs and then creates a Snapshot copy.
Case 2: Thin Provisioning by Allocating Storage as Required
The customer described in this case study is a Fortune 1000 IT consulting and service company that is growing at a rapid pace. The company has 35,000 employees around the world and is heavily dependent on e-mail for communication. The organization has deployed Microsoft® Exchange and is hosted on NetApp storage systems with over 20TB of storage utilization.

Recently this company merged with a 10,000-employee organization to expand its services into South America and has plans to consolidate all the new users into the organization’s existing Exchange infrastructure. The IT team has decided to complete the migration in a 2-year time frame, migrating about 1,250 users per quarter. Because they are extremely happy with the existing NetApp solutions, the company has decided to go with NetApp for their additional storage infrastructure.

Business Requirements

- **Scalability:** Allow storage capacity additions without downtime, enabling end users to be more productive.
- **Cost:** Use the storage effectively on a requirement basis and sustain the organization’s growth rate while reducing the overall cost of Exchange storage management.

NetApp Solution Summary
To meet the cost objectives of the organization, NetApp suggested that the customer use the thin provisioning feature with NetApp storage systems. Thin provisioning would enable the customer to plan investment on a phase-by-phase basis based on the consolidation process, rather than investing in bulk storage, which would result in high cost of ownership and underutilized storage.

Currently the organization uses around 20TB of storage for their 35,000 mailboxes. The addition of 10,000 more mailboxes would require them to purchase 9.2TB of storage up front. With the use of NetApp thin provisioning capability, the organization would need to purchase only 1.15TB of storage per quarter for Exchange consolidation, helping them avoid underutilization of storage by adding storage only as required.

For this organization it was sized to have 4 Exchange servers with 4 storage groups each and each storage group with 2 LUNs for database and logs. The below diagram shows how one single LUN in the storage group is resized using SnapDrive for Windows.

**Figure 19** Size of a single LUN in an Exchange Storage group before merger

**Figure 20** During the first quarter of the merger, the storage administrator added just 500GB of storage.

**Figure 21** After the first quarter, the storage administrator added an additional 500GB of storage.
Configuring Thin Provisioning

### Step 1
Configure the volume space management options:
- Enable Snapshot auto-delete so that older Snapshot copies are deleted automatically to free up space.
- In case of space contention, set the volume to grow first before trying to delete Snapshot copies.

### Step 2
As in the previous case study, NetApp Operations Manager can be used for monitoring volumes and aggregates.

### Step 3
The customer is already using SnapDrive for Windows and SnapManager® for Exchange solutions to simplify the backup operations of their Exchange database.

Using SnapDrive for Windows, the administrator can increase the storage size without any interruption to the service.

### Step 4
The administrator should constantly monitor the LUN usage, and when the LUN is about to get full, should increase the LUN size before the application produces write errors.

### NetApp Solution Benefits
- The customer was able to plan their storage for Microsoft Exchange database files and was highly impressed that the virtual disk can be expanded at any time without any disruption to the mail service.
- The customer saw a large reduction in investment because storage was procured only as needed.
Case 3: Thin Provisioning for Disk-to-Disk Backup
The customer described in this case study is a large company that sells backup services to its internal customers with a fixed retention guarantee (normally 45 days). The customer utilizes NetApp storage systems for both primary and secondary storage.

Business Requirements

Primary Storage and Application Environment
Characteristics of the primary storage requiring backup include:

- 72 NetApp storage systems with about 900TB of capacity.
- Retain 7 days of Snapshot copies on local storage for quick restores.
- Databases range from 100GB to 6TB in size.
- Approximately 150 groups and services are served by this storage.

Oracle Databases are the most critical and most volatile of the applications supported by this storage. Each database is considered independent; this means that it must be possible to back up and (more importantly) restore each one individually. Database turnover is often very low, but at times may reach a 100% rate of change because of people loading new information. The storage team has no control over or knowledge of what might occur on particular primary storage volumes, so the backup system has to adapt readily.

Secondary Storage and Disk-to-Disk Backup Environment
The secondary storage and backup environment consists of:

- Six NetApp NearStore® R200 storage systems using 320GB SATA disks with approximately 430TB of total raw capacity
- NetApp SnapVault® software:
  o SnapVault starts with a baseline copy on secondary storage that mirrors the source volume or qtree. (A qtree is a subvolume that has its own quotas and permissions.)
  o When a nightly backup is scheduled, SnapVault is used to create a Snapshot copy of the primary volume and to transfer to secondary storage only the blocks that have changed. (For databases, in-house scripts put the database in hot backup mode before creating a Snapshot copy.)
  o Snapshot copies are maintained on secondary storage for a prescribed time so that data can be restored from any point in time.
  o Approximately 800 qtrees are in SnapVault relationships.
  o From 14 to 45 days’ worth of SnapVault backups are retained for each qtree.

Problems
After about a year running this configuration, it became clear to the customer that differences in the change rate of different data sets were resulting in significant underutilization of the R200 systems. Utilization was only at 40%, yet the IT team was always concerned about secondary storage space because it was almost fully allocated. Manually managing 800 separate qtrees was impractical and painful.

NetApp Solution
NetApp demonstrated thin provisioning to the company’s storage administrators, and the IT team recognized an opportunity to leverage this approach to solve its backup challenges. The team found thin provisioning more appealing for its backup environment because performance wasn’t as big a concern—secondary storage was only occasionally accessed for restores—and it was possible to make changes to the backup environment as necessary (move qtrees to new aggregates and so on) without affecting production applications.

Configuring Thin Provisioning
Implementing thin provisioning was easy. The IT team was required to make only two adjustments to the volumes that housed the secondary qtrees for each SnapVault relationship:

- Changed volume guarantee setting to None.
- Sized each volume to match the size of the aggregate containing the volume.

With these changes, any volume can potentially grow to the full size of its aggregate, but no volume is guaranteed space. All volumes are free to grow as long as free space exists.

As a safety measure, the company created one “fully guaranteed” volume in each aggregate containing 20% of the total space. In normal operation this volume is not used, but serves only as an emergency backstop. If
an aggregate fills unexpectedly, a storage administrator can release this space so that operations can continue while rebalancing the distribution of qtrees between different aggregates.

Changes to Monitoring Practices
The alerting and monitoring done by NetApp Operations Manager were customized to account for the oversubscription of the aggregates and the need to provide a more appropriate “aggregate full” threshold. The company also changed from a policy of monitoring free space on volumes to monitoring free space on aggregates.

NetApp Solution Benefits
This thin provisioning methodology has been in place for a year with no outages, and no aggregates have been filled. Before the migration started, the company was concerned with free space almost every day, but as the migration went forward, it continuously got back free space from formerly underutilized volumes. This free space made it possible to add new customers and services into the backup system without purchasing additional storage. Over the course of the last year, primary storage capacity has grown from 500TB to 900TB without requiring any additional secondary storage capacity. Before the switch to thin provisioning, the company had been considering adding an additional R200.

This particular data center was continuously pinched for floor space, power, and cooling, so this savings represents a significant benefit beyond the savings in capital outlays. The company has been able to delay the purchase of any new secondary storage for a year as a result of thin provisioning and the increased efficiency it provides. Storage utilization went from less than 40% (due to mostly underutilized volumes) to closer to 70%.

8. Summary
NetApp storage systems and manageability applications provide a complete set of solutions to implement thin provisioned storage. Organizations who implemented NetApp thin provisioning technology witnessed the simplicity of the solution to quickly bring up the service for their business needs to meet service-level agreements and also reduced the cost of investment and operations by buying storage inline with the business needs.

9. Additional Information

For more information, refer to the following resources.


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