DS8000 Easy Tier
and Storage Tier Advisor Tool Demo

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Overview

- Easy Tier provides **automatic volume management** capabilities
  - Sub-volume drive tiering
  - Manual command based volume relocation
  - Automated drive utilization balancing to remove hot spots or populate new, empty ranks

- Easy Tier provides
  - A command line interface and a GUI for setup and management
  - Storage Tier Advisor Tool (STAT) for I/O analysis and projected benefits

- Easy Tier is a **licensed advanced function** for the DS8700/DS8800/DS8870
  - **No charge** – but you still have to order the feature and activate the license
  - Supported by all server platforms with no additional software or host configuration
  - No license is required to “monitor” and run STAT tool (described later)
Why Easy Tier – How Did We Get to this Point?

- Increases in the size of the smallest Hard Disk Drives available
  - The move to 2.5” technology has provided some relief for this issue but this is only temporary
  - Customers are installing larger DDMs with each storage system refresh
    - Do you remember when the ESS supported 9.1 GB DDMs? How about the VSS with 4.5 GB?
- Relatively small improvements in I/O latencies and throughput when compared to processor speeds
  - 10K RPM and 15K RPM drives have been around for years – where are the 20Ks?
  - Not much performance improvement in average seek times
  - Longer term more significant changes are expected to software, server and storage architectures (e.g., storage class memory)
- Significant cost differential between Solid State Drives and traditional Hard Disk Drives
  - Moving entire environments to SSD is not currently affordable for many customers
  - No short term relief in pricing models from SSD manufacturers
- Desire to reduce overall storage TCO by enabling storage tiering in a more automated and granular manner
  - The operational costs of manual placement are not acceptable to most clients
  - The price differential between SSD, enterprise and nearline drives make tiering extremely attractive from an acquisition cost perspective
Cost versus Performance

- **Tier 0**: Ultra High Performance Solid State Drives
- **Tier 1**: High Performance Enterprise Drives
- **Tier 2**: Low Performance Nearline Drives
- **Tier 3**: Archive No Access Tape/Punch Cards/Paper Tape

Cost Per Gigabyte vs. Performance
Configuration Optimization versus Performance Improvement

- Easy Tier is **not application aware** and it is entirely possible that **manual data placement** could provide more application specific performance improvements
  - The majority of storage administrators do not have the skills nor the time to do this well even if they fully understood the details of each application

- The objective of Easy Tier is to optimize the usage of a particular environment by placing and distributing data appropriately on the underlying storage media **without expert input and manual intervention** — we’re trying to make it EASY
  - By doing this at a granular sub-volume level it enables this to be done efficiently without making changes in the volume configuration or application data layout

- Data movement and placement is based on **historical data access patterns**
Easy Tier Processing Cycle

- Performance data collected every 5 minutes
- Data collected is for rank activity not I/O from hosts
- Workload analysis performed at least every 24 hours
- Takes into account both short term and long term data
- Extents categorized based on small I/O activity
- Cost benefit analysis performed to determine if movement of data will improve overall performance
- Movement of extents scheduled
Easy Tier - Workload Learning

Performance monitoring and reporting is available to track the I/O demand from applications and I/O service time from storage device.

Performance data is collected for multiple durations, hours, days and weeks.

Data collection period = 5 minutes
For all active extents

Heatmap and I/O Density Report

Applications

Virtual Disk

Smart Monitoring

Solid-state

Enterprise - FC / SAS

Nearline - SAS / SATA
Easy Tier Data Collection

- Easy Tier regularly collects **backend performance data** for each extent on the DS8000 every 5 minutes
  - Not host I/O

- This activity is broken down by **reads and writes & large I/O and small I/O** for the analysis code to evaluate which data should be moved
  - Large I/Os are those which are basically a full track in size

- Easy Tier only considers the **small I/O** when looking at prioritizing the extents to be moved.
  - Any tracks that are staged as full tracks in track mode for read misses will therefore not be considered in this decision criteria – these usually are a result of sequential access patterns

- Large I/Os are considered to evaluate whether ranks or device adapters may become overloaded by moving extents to SSDs
Heat and Skew

- **Hot data**
  - Hot data is simply extents that have more I/O workload, relatively speaking, when compared to other extents within the extent pool and tier

- **Cold data**
  - Cold data either has low (or no) I/O workload. Cold data would not benefit from a higher tier and thus is not promoted and is considered for demotion

- **Warm data**
  - Warm data is the rest of the workload that is not considered hot or cold. Warm data could be promoted – but that would depend on the workload level and available resources

- **Skew**
  - Highly skewed workload has a small number of hot extents
  - Low skewed workload has a more even distribution of workload to extents
Workload Skew
Easy Tier “Versions”

- Easy Tier 1 (DS8700 R5.1)
  - Automated cross-tier performance management for **SSD/HDD hybrid pools**
  - Manual mode management support for *dynamic extent pool merge and dynamic volume relocation*

- Easy Tier 2 (DS8700/DS8800 R6.1)
  - Automated cross-tier performance or storage economics management for hybrid pools with *any 2 tiers* (SSD/ENT, SSD/NL or ENT/NL)
  - Automated *intra-tier performance management* (auto-rebalance) in hybrid pools
  - Manual mode management support for *rank depopulation* and optimized *volume restriping* within non-managed pools (manual volume rebalance)

- Easy Tier 3 (DS8700/DS8800 R6.2)
  - Automated cross-tier performance and storage economics management for hybrid pools with *3 tiers* (SSD/ENT/NL)
  - Automated *intra-tier performance management* in both hybrid (multi-tier) as well as *homogenous (single tier) pools* (auto-rebalance)
  - *Thin Provisioning support* for Extent Space Efficient (ESE) Volumes

- Easy Tier 4 (DS8700/DS8800 R6.3 and DS8870)
  - Support for *encryption capable environments*
    • DS8800 and DS8870 has FDE capable SSD and nearline
## Disk Tiers

- **DS8700**
  - **Tier 0**
    - Solid-state drives (SSD)
      - 73 GB
      - 146 GB
      - 600 GB
  - **Tier 1**
    - Fibre Channel Enterprise drives
      - 146 GB/15K
      - 450 GB/15K
      - 600 GB/15K
      - FDE drives
  - **Tier 2**
    - SATA nearline drives
      - 2 TB/7.2K

- **DS8800**
  - **Tier 0**
    - Solid-state drives (SSD)
      - 300 GB
      - 400 GB
      - FDE drives
  - **Tier 1**
    - SAS Enterprise drives
      - 146 GB/15K
      - 300 GB/15K
      - 600 GB/10K
      - 900 GB/10K
      - FDE drives
  - **Tier 2**
    - SAS nearline drives
      - 3 TB/7.2K
      - FDE drives

- **DS8870**
  - **Tier 0**
    - Solid-state drives (SSD)
      - 400 GB
      - FDE drives
  - **Tier 1**
    - SAS Enterprise drives
      - 146 GB/15K
      - 300 GB/15K
      - 600 GB/10K
      - 900 GB/10K
      - FDE drives
  - **Tier 2**
    - SAS nearline drives
      - 3 TB/7.2K
      - FDE drives

Drive sizes shown are for example and not all drives are shown.
Operating Modes

- **Easy Tier Automatic Mode**
  - Promote/demote extents (sub-volume) within tiers of disk in same extent pool
    - Requires multitier or hybrid extent pool to promote/demote
  - Homogeneous pool rebalancing
    - Balances the load on the ranks within a given tier in an extent pool
  - Rebalance the workload when ranks (extents) are added to the extent pool

- **Easy Tier Manual Mode**
  - Dynamic volume relocation
  - Dynamic extent pool merge
  - Rank depopulation
  - Restripe a volume within the same pool
Easy Tier - Data Relocation Options
Manual Mode (Volume Level) and Automatic Mode (Extent Level)

Manual Mode
Volume Based Data Relocation

Automatic Mode
Extent Level Data Relocation

Automatic extent level data relocation enabled in a Merged Extent Pool
Easy Tier – Automatic Mode Overview

- Extent Migration Plan built based on I/O statistics collected (heat)
- Dynamically relocates a logical volume’s extents
  - Hot extents relocated to higher performance class of disk (enterprise → SSD)
  - Cold extents relocated to lower performance class of disk (enterprise → Nearline)
- Extent level promotion/demotion requires mixed technologies in a merged extent pool (between any two or three tiers), for example:
  - SSD + Enterprise + Nearline
  - SSD + Nearline or
  - Enterprise + Nearline
- DS8000 Extent Size
  - 1GiB for FB
  - 3390 Mod 1 (0.94 GB) for CKD
Easy Tier Automatic Mode

- **Promote extent**
  - Extent promotion occurs **one tier at a time**
    - If all three tiers are present in a hybrid pool promotion must go through intermediate (adjacent) tier

- **Demote extent**
  - Like promotion, demotion is **one tier at a time**

- **Auto-rebalance**

- **Micro-tiering**

- **Automatic mode works at the extent (sub-volume) level**
  - Opposed to manual mode which operates only on the entire volume
Easy Tier – Automatic Mode Promotion/Demotion

Mixed Technology Extent Pool

Higher Performance Tier Ranks

- Hot Extents
  - Migrate Up

Lower Performance Tier Ranks

- Cold Extents
  - Migrate Down

Logical Volume

Extent Virtualization
Auto Rebalance

- Extents moved between ranks of the same tier to balance workload
- Balances rank skew due to
  - Workload
  - Change in resources
- Proactively avoids hot spots
- Eliminates need to manually re-stripe extents
- Begins after 6 hours by default
Easy Tier – Homogeneous Pool Rebalancing

- Easy Tier will automatically rebalance within a homogeneous extent pool
  - Reduces skew and hot spots within a rank and redistributes extents across ranks within the homogeneous pool
- New for R6.3 – support for FDE ranks
- Six hour learning cycle

![Diagram showing rank rebalancing and natural performance skew](image-url)
Micro-tiering

- Easy Tier automatic mode can also help intra-tier extent pool management
  - Same class of drives but different device geometries
    - Example:
      - 146 GB/15K + 450 GB/10K in same extent pool
      - 300 GB/15K + 300 GB/10K in same extent pool
      - 300 GB SSD + 400 GB SSD in same extent pool
      - RAID-5 + RAID-10 in same extent pool
  - There is no promote/demote capability within the same drive class
    - Micro-tiering is best thought of as a rebalance action
    - Rebalance can occur if skew is significant
    - 6 hour learning cycle
  - Not driven by extent heat but rather rank utilization
    - Based upon performance characteristics of the rank
Micro-tiering Considerations

- For new configurations, would not recommend planning for micro-tiering
  - Probably more likely that an upgrade would introduce different drives within a class or tier

- Plan on using disk modeling tools to model mixed pool performance characteristics
  - May need to model slowest drive in tier and base assumptions on worse case

- Be aware of access densities and I/O rate to the drives and ranks
  - Number of drives to support workload is critical for workload planning

- No official IBM benchmarks or performance studies on micro-tiering have been published
Easy Tier Auto Mode Extent Migration Types

- **Promote & Swap**
  - Move hot data to higher performing tiers.

- **Warm Demote**
  - Prevent performance overload of a tier.

- **Cold Demote**
  - Identify coldest data and move it to lower tier.

- **Auto-Rebalance**
  - Re-distribute extents within a tier to balance utilization across ranks for maximum performance.
  - Move and swap capability

*Migrations only happen between adjacent tiers*
Easy Tier – Manual Mode Overview

- Easy Tier Manual Mode allows a user to perform the following actions:
  - **Dynamic Volume Migration**
    - User can change a logical volume’s storage technology by dynamically relocating between extent pools
    - User can change a logical volume’s extent allocation algorithm (EAM) (e.g. can re-rotate extents within the target extent pool)
  - **Dynamic Extent Pool Merge**
    - User can merge two existing extent pools without moving data
      - Consolidate extent pools with equivalent disks
      - Merge extent pools with to create a mixed technology extent pool for Automatic Mode
  - **Rank Depopulation**
    - Storage Administrator can ask that a rank be removed from an extent pool
    - Automatic, non-disruptive and transparent to host access, the used extents will be reallocated to other ranks in the pool and rank freed
  - **Manual Volume Rebalance**
    - Redistributes a volume’s extents within a non-managed single-tier pool
    - Same pool and can change EAM
Dynamic Volume Relocation/Migration

- Dynamically migrates a volume from its current extent pool to another extent pool
  - During the physical move, the volume remains online and accessible

- Limitations
  - The volume must remain in extent pools associated with the same SFI server
  - The two extent pools must have the same storage type (FB or CKD)
  - The volume can not be a space efficient (TSE) volume
Dynamic Volume Relocation

manageckdvol –action migstart –eam rotateexts p10 1004
Dynamic Extent Pool Merge

- Extent Pool Merge allows storage administrator to merge a source extent pool into a target extent pool
  - All volumes remain online and accessible to attached servers
  - Effective way to create a hybrid or multitier extent pool for automatic mode
  - Effective way to create a larger homogeneous extent pool

- Merge accomplishes
  - Changes the assignment of the source ranks to the target extent pool
  - Changes the assignment of volumes and space efficient repository (if any) to the target extent pool
  - Deletes the source extent pool that now has no ranks or volumes assigned anymore

- A merge is a logical operation – no physical movement of extents occur during a merger.
Dynamic Extent Pool Merge Limitations

- Both source and target extent pools must be associated with the *same server affinity* or rank group
  - No cross server mergers from server 0 to server 1
- Both source and target extent pools must have *similar storage types* (FB or CKD)
- Combined extent pool can not exceed 2 PB or more of capacity
  - Including logical capacity of ESE volumes
- Only one extent pool can contain a space efficient repository
- Neither extent pool can have an active manual volume migration in process while a merge is being performed
Dynamic Extent Pool Merge process

Before Extent Pool Merge

- Extent Pool 0
  - Rank 0
  - Rank 2
  - Rank 4

- Extent Pool 10
  - Rank 10
  - Rank 12
  - Rank 14

After Extent Pool Merge

- Extent Pool 0
  - Rank 0
  - Rank 2
  - Rank 4
  - Rank 10
  - Rank 12
  - Rank 14

chextpool –merge p10 p0
Rank Depopulation

- Rank depopulation provides the capability to remove and unassign a rank from an extent pool
  - All allocated extents on the rank are moved to other ranks in the extent pool
  - There must be sufficient free extents in the pool to depopulate the rank
    - If not enough free extents the command fails

- Useful for recapturing vacated capacity for reutilization
  - FB to CKD

- Useful for changing the RAID format of a rank
  - Example: change from RAID-5 to RAID-6 format
Rank Depopulation

**Before Rank Depopulation**
- Extent Pool 0
- Rank 0
- Rank 2
- Rank 4

**After Rank Depopulation**
- Extent Pool 0
- Rank 0
- Rank 4

**Unassigned**
- Rank 2

**chranks -unassign r2**
Manual Volume Rebalance

- Rebalance provides a mechanism to redistribute the extents of a volume within non-managed homogeneous extent pool
  - Effective way to restripe volumes if additional capacity is added to the pool or if you recently merged extent pools
  - Redistribute the extents if wanting to change from Rotate Volumes to Rotate Extents

- Limitations
  - Manual rebalance is only supported in single tier extent pools – not hybrid pools
  - Sufficient extents must be available on ranks in the pool
    - If some ranks have no available extents, than those ranks are omitted from the new allocation and the resulting volume may be constrained to too few ranks
  - Can not rebalance track space efficient volumes
Manual Volume Rebalance

managefbvol -action migstart 1000-101a
Easy Tier – Manual Mode Summary

- **Migrate Volume** (Target Extent Pool, Extent Allocation Method)
  - Can specify current extent pool or another extent pool
  - Can specify extent allocation method (rotate volumes or rotate extents)

- **Pause/Resume Volume Migration**
  - Pause puts volume in *migration paused* configuration state and stops initiation of any new extent migrations on a volume
  - Resume puts volume in *migrating* configured state and continues migration

- **Cancel Volume Migration**
  - Nullifies volume migration if it has not started and puts volume in *normal* configuration state
  - Stops volume migration if it has started and puts volume in *migration cancelled* configuration state. Can request migrate volume to source or target extent pool to retry.

- **Merge Extent Pool**
  - “Moves” all volumes in the source extent pool to the target extent pool
  - Deletes source extent pool if merge is successful

- **Rank Depopulation**
  - Can use Easy Tier to depopulate a rank and remove from an extent pool
  - Automatic, non-disruptive and transparent to host access
Easy Tier – Supported Environment and Restrictions

- Supported in DS8700 R5.1+ and DS8800 R6.1+ and all DS8870s

- Automatic Mode and Volume migration supported on standard logical volumes and Thin Provisioned volumes (ESE) starting with R6.2

- Track Space Efficient (TSE) volumes are not Easy Tier managed
  - Can reside in an extent pool managed by Automatic Mode
  - Volume migration is not supported on space efficient volumes

- Cannot migrate between extent pools on different storage images (0 / 1)
Easy Tier – Supported Environment and Restrictions - continued

- **Copy services considerations**
  - Easy Tier optimization of data on the primary system is not reflected at the secondary

- **Can merge any two extent pools except:**
  - Both must be same extent type (CKD or Fixed Block)
  - At most, one of two extent pools can have a space efficient repository
  - At most, one of one of two extent pools can have virtual capacity
  - Not allowed if one extent pool is homogeneous with SSD disks and additionally has space efficient repository or virtual capacity configured

- **You must have free extents on ranks for Easy Tier to function**
  - Plan on having approximately 10 free extents per rank in the pool
    - Allows Easy Tier to promote/demote and rebalance
    - Example: 5 ranks in the pool would recommend 50 free extents in the pool
Easy Tier and Encryption

- Easy Tier manual mode has always supported encryption capable machines
  - Dynamic volume migration and extent pool merge

- With the introduction of FDE drives for SSD and Nearline drive tiers, Easy Tier automatic mode will now be supported on encryption capable DS8800 and DS8870s for both 2 tier and 3 tier implementations
  - Promote with 2 or more tiers of FDE drives installed
  - Homogeneous extent pool rebalance – even if only one tier of FDE drives are installed

- DS8700 with R6.3 and Enterprise FDE drives could use Easy Tier automatic mode
  - Homogeneous extent pool rebalance (enterprise drives only available)
  - No promote/demote capability as no FDE SSD/Nearline drives on DS8700
Easy Tier – Workload Considerations

- Implementation Characteristics
  - Extent size is
    - 1 GiB on FB
    - 3390-1 equivalent on CKD
  - Automatic mode plan generation window is 24 hours

- Some workloads may not benefit significantly from Automatic Mode
  - Hot spots are small in size and uniformly distributed across extents such that all extents exhibit equal temperatures – for example, unusually low skew
  - Hot spots vary over time such that they are uniformly distributed given a large enough monitoring period
  - Critical workload to be optimized is intermixed with other workloads that result in a non-optimal extent placement
Easy Tier – Copy Services

- Copy services is not aware of Easy Tier data optimization
  - Any manual volume level migrations should be performed on both the primary and secondary system
    - In the event of a failover, data optimized as primary and secondary reflect the same data placement
  - In Automatic Mode, relocation of extents on the primary system is not reflected at the secondary
    - I/O workload being collected at the primary and secondary are different
      - Normal production workloads to the primary versus write only to the secondary
      - Easy Tier will make different optimization decisions for the different workload profiles
    - Applies to Metro Mirror, Global Mirror and z/OS Global Mirror
  - Will take time to get to an optimized environment in the event of a failover
    - Easy Tier will have to analyze the production workload, relearn and redistribute data based on this workload

- Easy Tier can manage Thin Provisioned (ESE) volumes
Tools

- **Storage Tier Advisor Tool (STAT)**
  - Extracts heat data collected by Easy Tier for volumes that are being monitored
  - Uses a DOS tool to create an HTML file

- **Disk Magic**
  - Disk Magic supports 5 predefined skew levels for prediction with Easy Tier
  - Disk Magic uses this skew setting to predict the number of I/Os
    - Higher skew results in a more aggressive sizing
  - See Disk Magic “printed help” file in the Disk Magic program directory

- **FLASHDA (z/OS only)**
  - Identifies what datasets and devices have the highest accumulated read-only disconnect time

- **IBM Tivoli Storage Productivity Center (TPC)**
Performance Metrics

- Easy Tier continually monitors the back end rank utilization and records the following statistics for each active extent
  - Reads and writes
  - Small block I/O
  - Large block I/O
  - Latency
  - I/O rate
  - Data transferred

- The DS8000 maintains a historical set of data known as DPA data. This data can be retrieved from the DS8000 only by IBM support personnel for further analysis under special circumstances.
Migration Plan

- Easy Tier auto mode creates migration plans once enabled
  - Plans are generated for both auto-rebalance and cross-tier migrations
    - Auto-rebalance plans are generated every 6 hours
    - Cross-tier migration (promote/demote) are generated at least once every 24 hours
    - No extent migration will occur until the plan is generated
  - Users cannot set the plan start/end times
  - Easy Tier license must be installed before any ET functions will execute

- Easy Tier creates one migration queue per extent pool
  - Each pool is optimized independently
    - One extent pool is not compared to another extent pool

- Decision windows for easy tier are based on short term and long term extent heat
  - Short term heat has higher weight compared to long term extent heat
    - Short term window is past 24 hours
    - Long term window is past 7 days
Enabling Easy Tier

- **License**
  - Order Easy Tier feature code #7083
  - Download license key from DSFA and apply it to the DS8000

- **Enable Easy Tier**
  - Storage Image Properties (DS GUI)
  - chsi –Eautomode all | tiered | none storage_image_id
    - **Auto Mode**
      - all: Automatically manage all single and multi-tier pools
      - tiered: Automatically manage multi-tier pools only
      - none: Do not automatically manage any pools
  - chsi –Etmonitor all | automode | none storage_image_id
    - **Monitor**
      - automode: Only volumes managed by Easytier auto mode are monitored
      - all: All volumes in the system are monitored.
      - none: No volume is monitored.
Considerations

- **Micro Tiering**
  - Multiple drive geometry within the same tier class
    - 146 GB/15K + 600 GB/10K enterprise
    - 300 GB SSD + 400 GB SSD
    - 1 TB nearline + 2 TB nearline

- **Remote Copy**
  - Workload at primary in a Metro Mirror or Global Mirror relationship is very different from workload at secondary
    - In the event of a failover, production workload may not be optimized

- **Dramatic changes in workload**
  - Workload changes dramatically and develops a new workload pattern
    - Easy Tier will need time to learn the new workload and handle extent migration
    - End of year processing
Storage Tier Advisor Tool
What is STAT?

- Storage Tier Advisor Tool

- No charge tool available for download from IBM that will process heat data files from DS8000, SVC, and V7000, producing HTML reports based on the collected data
  - Get the latest code level – it is downward compatible for heat data that is obtained from older versions of DS8000 or from SVC/V7000
  - The download is an ISO file. You can burn a CD or use a tool to extract information from an ISO.
    - I use vCdControlTool from Microsoft.
Offload Statistics for STAT
– Select Storage Image - Export Easy Tier Summary Report
Offload Statistics for STAT – Popup Windows

1. Export Summary Report
2. Opening SFSTN211.2011.4.29.11.54.7.zip
3. Downloads window
Offload Statistics for STAT
– Zip File Containing 2 Files for Input to STAT
Offload Statistics for STAT - DSCLI

dscli> offloadfile -etdata c:\progra~1\ibm\stat


CMUC00428I offloadfile: The etdata file has been offloaded to c:\progra~1\ibm\stat\SF75TN210ESS01_heat.data.

CMUC00428I offloadfile: The etdata file has been offloaded to c:\progra~1\ibm\stat\SF75TN210ESS11_heat.data.
Run STAT against Data in the 2 Heat Files

- Execute STAT command (unzip offloaded files to directory with stat executable or point to directory)

  C:\Program Files\IBM\STAT> `stat –o Data_files SF75TN210ESS01_heat.data SF75TN210ESS11_heat.data`

  CMUA00019I The STAT.exe command has completed.
  C:\Program Files\IBM\STAT>

- STAT command will create / update sub-directory “Data_files” and provide “index.html”
So, what is heat?

- Easy Tier classifies extents based on the Exponential Moving Average (EMA) of the **backend** response time which we refer to as the “heat” value of the extent
  - Extents with a “heat” of 0 are classified as cold. This does not mean zero activity but a low enough level that the EMA is zero.

- In order to divide the extents into warm and hot categories Easy Tier takes the highest heat value **per pool and tier**, divides this by 10, and classifies the lowest 10% as warm, the rest as hot

- Heat is relative to the current environment and tier. Hence an extent that is hot in one configuration or on one disk type could be warm on another or vice-versa
  - So long as the EMA of the IOPS is >0 we can classify an extent as hot. This does not mean it will be moved to SSD (or higher tier) as it still must satisfy the cost/benefit analysis
System Summary

The data is collected from Fri Apr 13 16:02:50 2012 to Fri Apr 27 07:29:33 2012
Storage Tier Advisor Tool version: 8.2.0.0

<table>
<thead>
<tr>
<th>Storage Pool ID</th>
<th>Capacity (GB)</th>
<th>Configuration</th>
<th>Tier Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>000A</td>
<td>21724</td>
<td>SSD + Enterprise + NL</td>
<td>Latest Warmstart: No Warmstart Latest Feedback: No Feedback</td>
</tr>
<tr>
<td>000B</td>
<td>21724</td>
<td>SSD + Enterprise + NL</td>
<td>Latest Warmstart: No Warmstart Latest Feedback: No Feedback</td>
</tr>
<tr>
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<td>Enterprise</td>
<td>Latest Warmstart: No Warmstart Latest Feedback: No Feedback</td>
</tr>
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<td>000E</td>
<td>12932</td>
<td>NL</td>
<td>Latest Warmstart: No Warmstart Latest Feedback: No Feedback</td>
</tr>
</tbody>
</table>

Legal Disclaimer:
The "Storage Tier Advisor Tool" uses limited storage performance measurement data from a user's operational environment to model potential unbalanced workloads on disk and array resources. It is intended to supplement and support, but not replace, detailed pre-installation sizing and planning analysis. It is most useful to obtain a "rule of thumb" system-wide performance projection of cumulative latency reduction on arrays and disks when a Solid State Disk configuration and the IBM Easy Tier™ function are used in combination to handle workload growth or slow management.

The "hot data" identification methodology in the tool is an engineering estimation based on expected cumulative latency reductions if the suggested Solid State Device configuration is used with the measured workload and storage configuration. Care has been taken in the development of this tool, but the accuracy of any prediction of performance improvement is subject to a variety of storage system configurations, conditions and other variables beyond the scope of this tool. Accordingly, actual results may vary.

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Systemwide Recommendations

Recommended SSD Configuration
Recommended Enterprise Configuration
Recommended NL Configuration

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The "hot data" identification methodology in the tool is an engineering estimation based on expected cumulative latency reduction if the suggested Solid State Device configuration is used with the measured workload and storage configuration. Care has been taken in the development of this tool, but the accuracy of any prediction of performance improvement is subject to a variety of storage system configurations, conditions and other variables beyond the scope of this tool. Accordingly, actual results may vary.

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Systemwide Recommendation – by Extent Pool

Recommended SSD Configuration

<table>
<thead>
<tr>
<th>Storage Pool ID</th>
<th>SSD Configuration</th>
<th>Predicted Performance Improvement</th>
<th>Total Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>Performance Improved by Existing Spare SSD Capacity (676GB)</td>
<td>0% ~ 13%</td>
<td>0% ~ 13%</td>
</tr>
<tr>
<td>0002</td>
<td>Performance Improved by Existing Spare SSD Capacity (676GB)</td>
<td>0% ~ 14%</td>
<td>0% ~ 14%</td>
</tr>
</tbody>
</table>

Recommended Enterprise Configuration

Recommended NL Configuration

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Storage Pool – Performance and Improvement Recommendations

Existing Tier Status

SSD Tier (Average Utilization of Rank IOPS is 11%)

<table>
<thead>
<tr>
<th>Rank ID</th>
<th>Storage Pool ID</th>
<th>Rank Type</th>
<th>Number of IOPS Threshold Exceeded</th>
<th>Utilization of Rank IOPS</th>
<th>Projected Utilization of Rank IOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>00001</td>
<td>SSD</td>
<td>0</td>
<td>11%</td>
<td>11%</td>
</tr>
</tbody>
</table>

Enterprise Tier (Average Utilization of Rank IOPS is 0%)

<table>
<thead>
<tr>
<th>Rank ID</th>
<th>Storage Pool ID</th>
<th>Rank Type</th>
<th>Number of IOPS Threshold Exceeded</th>
<th>Utilization of Rank IOPS</th>
<th>Projected Utilization of Rank IOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>00001</td>
<td>Enterprise</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>5</td>
<td>00001</td>
<td>Enterprise</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>6</td>
<td>00001</td>
<td>Enterprise</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>13</td>
<td>00001</td>
<td>Enterprise</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>14</td>
<td>00001</td>
<td>Enterprise</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
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<td>15</td>
<td>00001</td>
<td>Enterprise</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
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</table>

NL Tier (Average Utilization of Rank IOPS is 1%)

<table>
<thead>
<tr>
<th>Rank ID</th>
<th>Storage Pool ID</th>
<th>Rank Type</th>
<th>Number of IOPS Threshold Exceeded</th>
<th>Utilization of Rank IOPS</th>
<th>Projected Utilization of Rank IOPS</th>
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</thead>
<tbody>
<tr>
<td>8</td>
<td>00001</td>
<td>NL</td>
<td>0</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

1 Tier Demo

3 Tier Demo

Recommended SSD Configuration
Recommended SSD + Enterprise Configuration
Recommended Enterprise Configuration
Recommended NL Configuration
Volume Heat Distribution

LEGAL DISCLAIMER:
Volume Heat Distribution

Recommended SSD + Enterprise Configuration
Recommended Enterprise Configuration
Recommended NL Configuration
Volume Heat Distribution

<table>
<thead>
<tr>
<th>Volume ID</th>
<th>Configured Size</th>
<th>Tier</th>
<th>Capacity on Tier</th>
<th>Heat Distribution</th>
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</thead>
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<tr>
<td>0x0100</td>
<td>9G</td>
<td>SSD</td>
<td>6G</td>
<td>1G 3G 4G</td>
</tr>
<tr>
<td>0x0101</td>
<td>9G</td>
<td>NL</td>
<td>6G</td>
<td>1G 3G 4G</td>
</tr>
<tr>
<td>0x0102</td>
<td>9G</td>
<td>NL</td>
<td>6G</td>
<td>1G 3G 4G</td>
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<tr>
<td>0x0103</td>
<td>9G</td>
<td>NL</td>
<td>6G</td>
<td>1G 3G 4G</td>
</tr>
<tr>
<td>0x0104</td>
<td>9G</td>
<td>NL</td>
<td>6G</td>
<td>1G 3G 4G</td>
</tr>
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<td>1G 3G 4G</td>
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<td>NL</td>
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<td>0x0107</td>
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<td>6G</td>
<td>1G 3G 4G</td>
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References

- IBM System Storage DS8000 Easy Tier Redpaper - REDP-4667

- IBM System Storage DS8000: Architecture and Implementation - SG24-8886

- IBM System Storage DS8800 and DS8700 Performance with Easy Tier 3rd Generation - WP102024