SCSI-3 Storage Array Tutorial

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SCSI-3 Controller Command Standard

What is it?

- A model describing objects and the relationships between those objects within storage arrays
  - Sections one through five and the annexes of the SCC Standard

- Command set
  - Uses SCSI structures (CDBs, Parameters list, etc.)
  - Section six of the SCC Standard

- Command set is dependent on the model but the model does not require a SCSI command set
Terminology

- **SCSI-3 Storage Array**
  - A SCSI-3 device that controls multiple SCSI devices using the rules and commands defined in the SCSI-3 Controller Commands Standard
  - Contains one or more SACLs

- **Storage Array Conversion Layer (SACL)**
  - Translates input logical unit numbers into one or more output logical unit numbers
  - Routes logical block addresses to one or more logical units
  - May convert input logical block addresses to output logical block addresses
System Layering

- A system may contain zero or more SCSI Storage Arrays

- A system may contain one or more SACLs
  - May exist anywhere within the system
Typical System

Diagram:

operating system

software (driver)

HBA (initiator)

drive (target)  drive (target)

HBA (initiator)

drive (target)  drive (target)  ...  drive (target)
Software SAACL Branch

operating system

logical unit identifier (x) + logical block address (x)

software (driver)

SACL

logical unit identifier (y) + logical block address (y)

HBA (Initiator)

logical unit identifier (y) + logical block address (y)

drive (target)
Host Bus Adapter (HBA) SACL Branch

operating system

logical unit identifier (x) + logical block address (x)

software (drivers)

logical unit identifier (x) + logical block address (x)

HBA (Initiator)
SACL

logical unit identifier (y) + logical block address (y)

drive (target)
System With A SCSI-3 Storage Array Attached

operating system

software (driver)

HBA (initiator)

drive (target)

drive (target)

storage array (SACL)

drive (target)

drive (target)

drive (target)

HBA (initiator)

drive (target)

drive (target)

drive (target)

...
SCSI-3 Storage Controller SACL Branch

operating system

logical unit identifier (x) + logical block address (x)

software (drivers)

logical unit identifier (x) + logical block address (x)

HBA (initiator)

logical unit identifier (x) + logical block address (x)

storage array (target/initiator) SACL

logical unit identifier (y) + logical block address (y)

drive (target)
Multiple SACLs within one Branch

operating system

logical unit identifier (x) + logical block address (x)

software (driver)
SACL

HBA (initiator)

logical unit identifier (y) + logical block address (y)

storage array (target/initiator)
SACL

logical unit identifier (z) + logical block address (z)

drive (target)
SCSI-3 Storage Array Physical Objects

- Peripheral device: Any device identifiable as a SCSI peripheral device type:
  - Disk drives
  - Tape drives
  - Optical devices
  - etc.

- Component device: Any addressable device not identifiable as a SCSI peripheral device:
  - Controller electronics that contain a SACL
  - Non-volatile cache
  - Power Supply
  - Display
  - Keypad entry
  - Fan
SCSI-3 Storage Array Logical Objects

- **P_extent**: A contiguous block of logical block addresses on a single peripheral device.
  - A single p_extent cannot exist on more than one peripheral device
  - Used to:
    - Create redundancy groups
    - Modify redundancy groups
    - Create spares

- **Ps_extent**: A contiguous block of logical block addresses on a single peripheral device that excludes any logical blocks addresses identified as check data.
  - A single ps_extent cannot exist on more than one peripheral device
  - Ps_extents are a result of the creation of redundancy groups
  - Used to:
    - Create volume sets
    - Modify volume sets
SCSI-3 Storage Array Logical Objects (Cont.)

- Redundancy group: A grouping of one or more p_extent(s) that have a common type of protection
  - The logical block addresses of two or more redundancy group may overlap if the overlapping logical block addresses do not contain any check data

- Volume set: A grouping of one or more ps_extent(s) that provide a contiguous range of logical block addresses for reading and writing user data
  - The logical block addresses of volumes sets cannot overlap

- Spare: A p_extent, peripheral device, or component that will be automatically exchanged with a like object if that object fails
Addressing the SCSI-3 Storage Array

- Objects are directly or indirectly addressable
  - Directly addressable objects are:
    - Peripheral devices
    - Volume sets
  - Indirectly addressable objects are:
    - Peripheral devices
    - Volume sets
    - Component devices
    - Redundancy groups
    - Spares
Direct Addressing

- Any command may be sent

- Uses an 8-byte field split into 4 four 2-byte fields to address up to four levels of objects

- Each 2-byte field identifies and locates objects within a level

- The 2-byte field contains the address method to be used
  - Peripheral device addressing method
    - 63 buses
    - 256 peripheral devices per bus
  - Volume set addressing method
    - \(2^{14} - 1\) volume sets
Format of 2-byte field

- Peripheral device addressing format:
  
  Bit
  Byte    7   6   5   4   3   2   1   0
  n-1     0   0   BUS NUMBER
  n       TARGET/LUN

- Volume set addressing format:
  
  Bit
  Byte    7   6   5   4   3   2   1   0
  n-1     0   1   (MSB)
  n       LUN   (LSB)
## Format of 8-byte field

<table>
<thead>
<tr>
<th>Bit Byte</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
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<tbody>
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<td>0</td>
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</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
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<td>2</td>
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<td></td>
</tr>
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<td>3</td>
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<td></td>
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<td></td>
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<tr>
<td>4</td>
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<td>5</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **FIRST LEVEL ADDRESSING**
- **SECOND LEVEL ADDRESSING**
- **THIRD LEVEL ADDRESSING**
- **FOURTH LEVEL ADDRESSING**
The Missing Bus

- A bus number of zero in the 2-byte field for peripheral device addressing addresses the SCSI-3 storage array directly.
SCSI-3 Storage Array Base Address

- All SCSI-3 storage arrays have a base address
- The base address is logical unit number zero
- A value of 0000h in the 2-byte field for peripheral device addressing will address the base address
- All commands to objects that require indirect addressing are sent to the base address
Addressing Exception for SIP

- The Identify message and a mode page replace the 8-byte and 2-byte fields

- If there is no active LUN mapping mode page the Identify message contains the address method to be used
  - Peripheral device addressing method
    - VOLSEL field set to zero
    - 32 peripheral devices
  - Volume set addressing method
    - VOLSEL field set to one
    - 32 volume sets

- If there is an active LUN mapping mode page the Identify message contains
  - Base address addressing
    - Bits 5-0 set to zero
  - A pointer to one of 31 8-byte addressing fields
    - VOLSEL field set to zero
  - Volume set addressing method
    - VOLSEL field set to one
    - 32 volume sets
Format of the Identify Message and LUN Mapping Mode Page

- Format of Identify Message

<table>
<thead>
<tr>
<th>Bit</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>IDENTIFY</td>
<td>DISCRPRV</td>
<td>VOLSEL</td>
<td>LUN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Format of LUN mapping mode page

<table>
<thead>
<tr>
<th>Bit</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>PS</td>
<td>RESERVED</td>
<td></td>
<td>PAGE CODE (xxh)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>PAGE LENGTH (FAh)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>RESERVED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>RESERVED</td>
<td>ACTIVE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>(MSB)</td>
<td></td>
<td>LUN 1 MAPPING (LSB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>244</td>
<td>(MSB)</td>
<td></td>
<td>LUN 31 MAPPING (LSB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Notation for Addressing Examples

The conventions used within the examples are:

Layer 1  M:P:T or M:L or u
Layer 2  M:P:T or M:L or u
Layer 3  M:P:T or M:L or u
Layer 4  M:P:T or M:L or u

Where:
   M is the Address Method (2 bit field)
   P is the Bus Number (6 bit field)
   T is the Target (8 bit field)
   L is the Logical Unit Number (14 bit field)
   u means unused and set to zero (16 bit field)

Note: All of the examples use the peripheral device addressing method therefore M=0
Addressing

Operating System

Software (Driver)

HBA (Initiator)

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

SA(Targ/Init)
T1L0:0:0

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1
Example 1: Address Drive at Level 1
Example 2: Address Drive at Level 2
Example 3: Address Fan at Level 1

Operating System

Software (Driver)

HBA (Initiator)

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:1

Drive(Targ)
T1L0/L0:1:2

Drive(Targ)
T1L0/L0:3:2:0:1:1

LUN
1-0:0:0 2-0:0:0 3-u 4-u

LUN
1-0:3:2

SA(Targ/Init)
T1L0:0:0

Drive(Targ)
T1L0/L0:3:1

Drive(Targ)
T1L0/L0:4:1

Drive(Targ)
T2L0/L0:2:1

Drive(Targ)
T2L0/L0:2:2

Drive(Targ)
T2L0/L0:3:2:0:1:2

Drive(Targ)
T2L0/L0:3:2:0:2:1

Drive(Targ)
T2L0/L0:3:2:0:2:2

Drive(Targ)
T2L0/L0:2:2

Drive(Targ)
T2L0/L0:4:2

Drive(Targ)
T1L0/L0:2:1
Indirect Addressing

- All indirect addressing fields are contained within commands sent to a SCSI-3 storage arrays’ base address

- Only commands defined by the SCC standard use indirect addressing

- Any commands that contain indirect addressing must be sent to the base address of a SCSI-3 storage array

- A Logical Unit Type (4-bits) field contains type of object to address
  - Peripheral devices
  - Volume sets
  - Component devices
  - Redundancy groups
  - Spares

- A LUN (2-byte) field contains the logical unit number of the object to address
# Format on Indirect Addressing Fields

- **Data format of LOGICAL UNIT DESCRIPTOR**

<table>
<thead>
<tr>
<th>Bit Byte</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RESERVED</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RESERVED</td>
<td>LOGICAL UNIT TYPE</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(MSB)</td>
<td>LUN</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(LSB)</td>
<td></td>
</tr>
</tbody>
</table>
Proprieties of Objects

■ Protected objects
  • An object that can tolerate one or more objects failing without any loss of user data or availability
  • Objects that can be protected by using spares
    - Component devices
    - Peripheral device
    - P_extents
  • Objects that can be protected by using redundancy groups
    - Volume sets

■ Association of objects
  • A linking of like objects to form an object
    - P_extents become associated with a redundancy group during the creation or modification of that redundancy group
    - Redundancy groups become associated with a volume set during the creation or modification of that volume set
Proprieties of Objects (Cont.)

- Attachment of objects
  - The linking of objects to component devices
  - Any of the following objects may be attached to a component device:
    - Peripheral devices
    - Volume sets
    - Component devices
    - Redundancy groups
    - Spares
  - The behavior of attachments and their interactions with component devices are not defined in the SCC standard

- Covering of objects
  - The protection of objects using spares
  - Only like objects can be covered
  - Any of the following objects may be covered by spares:
    - Peripheral devices
    - P_extents
    - Component devices
  - When an object is covered it assumes all the characteristics of the failed object
Operations on Objects

- Adding objects
  - Adding an object makes it addressable
  - The following object may be added:
    - Peripheral devices
    - Component devices

- Exchanging objects
  - Replacing an object with a like object
  - Only like objects can be exchanged
  - Any of the following objects may be exchanged:
    - Peripheral devices
    - P_extents
    - Component devices
  - When an object is exchanged it assumes all the characteristics of the object it is replacing
Operations on Objects (Cont.)

- Removing objects
  - Removing objects makes them no longer addressable:
  - Any of the following objects may be removed:
    - Peripheral devices
    - Component devices
    - Redundancy groups
    - Volume sets
    - Spares
  - Any logical block addresses within a removed volume set become unassigned protected space
  - Any logical block addresses within removed redundancy group or spare become unassigned p_extents
  - The removing of a component spare removes the covering, however, the component remains addressable

- Rebuilding objects
  - The rebuild operation recreates protected space contents or any check data within a p_extent using check data and protected space contents from the remaining p_extents within the redundancy group
  - The regenerated protected space contents or any recalculated check data shall be written to the p_extent being rebuilt
Operations on Objects (Cont.)

■ Recalculating objects
  • The recalculate operation recreates check data from protected space contents
  • The recreated check data shall be written to the check data location being recalculated

■ Regenerating objects
  • The regenerate operation recreates inaccessible protected space contents from accessible check data and protected space contents
  • The recreated protected space contents is not saved

■ Verifying objects
  • The verify operation recreates check data from protected space contents and compare the recreated check data with the current check data
  • If the recreated check data does not match the current check data an exception condition shall be created
SCSI-3 Storage Array States

- Gives current operating condition of selected logical unit

- Base address states
  - Readying state: Indicates if any logical units within the SCSI-3 storage array being initialized and access is limited.
  - Non-addressable component failure state: Indicates one or more non-addressable part(s) have failed. (e.g. power supply failure, LED failure, cache failure, etc. that are not defined as component devices).
  - Abnormal state: Indicates one or more addressable devices within the SCSI-3 storage array are indicating a state other than available.
## SCSI-3 Storage Array States (Cont.)

### Volume set states

<table>
<thead>
<tr>
<th>Codes</th>
<th>States</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>Available</td>
<td>The addressed volume set is operational.</td>
</tr>
<tr>
<td>01h</td>
<td>Broken</td>
<td>The addressed volume set is capable of being supported but it has failed.</td>
</tr>
<tr>
<td>02h</td>
<td>Data lost</td>
<td>Within the addressed volume set data has been lost.</td>
</tr>
<tr>
<td>03h</td>
<td>Exposed</td>
<td>Within the addressed volume set data is not protected. In this state all data is still valid, however, a failure causes a loss of data or a loss of data availability.</td>
</tr>
<tr>
<td>0Ch</td>
<td>Protection disabled</td>
<td>Within the addressed volume set the generation of check data has been disabled. In this state all data is still valid, however, a failure causes a loss of data or a loss of data availability.</td>
</tr>
<tr>
<td>04h</td>
<td>Partially exposed</td>
<td>Within the addressed volume set one or more logical unit(s) have failed. In this state all data is still protected.</td>
</tr>
<tr>
<td>05h</td>
<td>Protected rebuild</td>
<td>One or more of the redundancy groups associated with the addressed volume set is in the process of a rebuild operation. In this state all data is protected.</td>
</tr>
<tr>
<td>06h</td>
<td>Not available</td>
<td>The addressed volume set is capable of being supported but has not been configured.</td>
</tr>
<tr>
<td>07h</td>
<td>Not supported</td>
<td>The addressed volume set is not capable of being configured.</td>
</tr>
<tr>
<td>08h</td>
<td>Readying</td>
<td>The addressed volume set is being initialized and access to the volume set is limited.</td>
</tr>
<tr>
<td>09h</td>
<td>Rebuild</td>
<td>One or more of the underlaying redundancy groups associated with the addressed volume set is in the process of a rebuild operation. In this state data is not protected.</td>
</tr>
<tr>
<td>0Ah</td>
<td>Recalculate</td>
<td>The addressed volume set is in the process of a recalculate operation.</td>
</tr>
<tr>
<td>0Bh</td>
<td>Spare in use</td>
<td>Within the addressed volume set a spare is being used. In this state all data is still protected.</td>
</tr>
<tr>
<td>0Dh</td>
<td>Verify in progress</td>
<td>Within the addressed volume set data is being verified.</td>
</tr>
<tr>
<td>0Eh-3Fh</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>40h-7Fh</td>
<td>Vendor Specific</td>
<td></td>
</tr>
</tbody>
</table>
### SCSI-3 Storage Array States (Cont.)

- **Redundancy group states**

<table>
<thead>
<tr>
<th>Codes</th>
<th>States</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>Available</td>
<td>The addressed redundancy group is configured.</td>
</tr>
<tr>
<td>01h</td>
<td>Exposed</td>
<td>Within the addressed redundancy group data is not protected. In this state all data is still valid, however, a failure causes a loss of data or a loss of data availability.</td>
</tr>
<tr>
<td>02h</td>
<td>Invalidated</td>
<td>Within the addressed redundancy group data has been lost. In this state the protected space is no longer intact.</td>
</tr>
<tr>
<td></td>
<td>Protected Space</td>
<td></td>
</tr>
<tr>
<td>03h</td>
<td>Not Available</td>
<td>The addressed redundancy group is capable of being supported but has not been configured.</td>
</tr>
<tr>
<td>04h</td>
<td>Not Supported</td>
<td>The addressed redundancy group is not capable of being configured.</td>
</tr>
<tr>
<td>05h</td>
<td>Partially Exposed</td>
<td>Within the addressed redundancy group one or more logical unit(s) have failed. In this state the protected space is protected.</td>
</tr>
<tr>
<td>0Ah</td>
<td>Protection disabled</td>
<td>Within the addressed redundancy group the generation of check data has been disabled. In this state all data is still valid, however, a failure causes a loss of data or a loss of data availability.</td>
</tr>
<tr>
<td>06h</td>
<td>Present</td>
<td>The addressed redundancy group is present but no other status is available.</td>
</tr>
<tr>
<td>07h</td>
<td>Protected Rebuild</td>
<td>The addressed redundancy group is in the process of a rebuild operation. In this state the protected space is protected.</td>
</tr>
<tr>
<td>08h</td>
<td>Rebuild</td>
<td>The addressed redundancy group is in the process of a rebuild operation. In this state the protected space is not protected.</td>
</tr>
<tr>
<td>09h</td>
<td>Recalculate</td>
<td>The addressed redundancy group is in the process of a recalculate operation.</td>
</tr>
<tr>
<td>0Bh</td>
<td>Verify in progress</td>
<td>Within the addressed redundancy group data is being verified.</td>
</tr>
<tr>
<td>0Ch-3Fh</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>40h-7Fh</td>
<td>Vendor Specific</td>
<td></td>
</tr>
</tbody>
</table>
SCSI-3 Storage Array States (Cont.)

• Peripheral device and p_extent states

<table>
<thead>
<tr>
<th>Codes</th>
<th>States</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>Available</td>
<td>The addressed peripheral device or p_extent is operational.</td>
</tr>
<tr>
<td>01h</td>
<td>Broken</td>
<td>The addressed peripheral device or p_extent is capable of being supported but it has failed.</td>
</tr>
<tr>
<td>02h</td>
<td>Not available</td>
<td>The addressed peripheral device or p_extent is capable of being supported but no device is connected.</td>
</tr>
<tr>
<td>03h</td>
<td>Not supported</td>
<td>The target is not capable of supporting a device at the addressed peripheral device or p_extent.</td>
</tr>
<tr>
<td>04h</td>
<td>Present</td>
<td>The addressed peripheral device or p_extent is present but no other status is available.</td>
</tr>
<tr>
<td>05h</td>
<td>Readying</td>
<td>The addressed peripheral device or p_extent is being initialized and access to the peripheral device or p_extent is limited.</td>
</tr>
<tr>
<td>06h-3Fh</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>40h-7Fh</td>
<td>Vendor Specific</td>
<td></td>
</tr>
</tbody>
</table>

• Spare states

<table>
<thead>
<tr>
<th>Codes</th>
<th>States</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>Available</td>
<td>The addressed spare is operational.</td>
</tr>
<tr>
<td>01h</td>
<td>Broken</td>
<td>The addressed spare is capable of being supported but it has failed.</td>
</tr>
<tr>
<td>02h</td>
<td>Not available</td>
<td>The addressed spare is capable of being supported but has not been configured.</td>
</tr>
<tr>
<td>03h</td>
<td>Not supported</td>
<td>The addressed spare is not capable of being configured.</td>
</tr>
<tr>
<td>04h</td>
<td>Present</td>
<td>The addressed spare is present but no other status is available.</td>
</tr>
<tr>
<td>05h</td>
<td>Spare in use</td>
<td>The addressed spare is being used.</td>
</tr>
<tr>
<td>06h-3Fh</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>40h-7Fh</td>
<td>Vendor Specific</td>
<td></td>
</tr>
</tbody>
</table>
### SCSI-3 Storage Array States (Cont.)

**• Component states**

<table>
<thead>
<tr>
<th>Codes</th>
<th>States</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00h</td>
<td>Available</td>
<td>The addressed component device is fully operational.</td>
</tr>
<tr>
<td>01h</td>
<td>Broken</td>
<td>The addressed component device is capable of being supported but it has failed.</td>
</tr>
<tr>
<td>02h</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>03h</td>
<td>ITTU</td>
<td>The addressed component device is the reporting component device. This state shall not be reported unless the command allows the reporting of multiple states. More that one component device may report an ITTU state in a single state request.</td>
</tr>
<tr>
<td>04h</td>
<td>Not available</td>
<td>The addressed component device is capable of being supported but no component is present.</td>
</tr>
<tr>
<td>05h</td>
<td>Not supported</td>
<td>The target is not capable of supporting a component on the addressed component device.</td>
</tr>
<tr>
<td>06h</td>
<td>Present</td>
<td>The addressed component device is present but no other status is available.</td>
</tr>
<tr>
<td>07h</td>
<td>Readying</td>
<td>The addressed component device is being initialized and access to the component device is limited.</td>
</tr>
<tr>
<td>08h-3Fh</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>40h-7Fh</td>
<td>Vendor Specific</td>
<td></td>
</tr>
</tbody>
</table>
Exception Conditions

Exception conditions indicate the following:

- a change occurred in the physical configuration,
- a change occurred in a volume set configuration,
- a change occurred in a redundancy group configuration,
- a change occurred in a spare,
- a change occurred in the operation state of the SACL,
- a repair action is requested (e.g. device is predicting failure),
- a repair action is required to restore the volume sets availability (e.g. power supply failure),
- a repair action is required to restore the volume sets level of integrity (e.g. device fails), or
- an error occurred.
Single Redundancy Group Example

- volume set user data
- redundancy group
- protected space
- check data
Multiple Volume Set Associated with a Single Redundancy Group Example

- check data
- volume set (1) user data (1)
- volume set (2) user data (2)
- assigned protected space
- unassigned protected space
- redundancy group

- volume set user data
- redundancy group
- protected space
- check data
Multiple Redundancy Groups Example

```plaintext
- check data (a)
- redundancy group (a)
- unassigned protected space (a)

- check data (b)
- redundancy group (b)
- unassigned protected space (b)
```

- volume set user data
- redundancy group
- protected space
- check data
Single Volume Set Associated with Multiple Redundancy Groups

- check data (a)
- redundancy group (a)
- assigned protected space (a)

- check data (b)
- redundancy group (b)
- assigned protected space (b)

- volume set user data
- redundancy group
- protected space
- check data