Repurposing Depopulation:
Extending storage device service lifetimes
Repurposing Depopulation
Extending storage device service lifetimes

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Agenda

- Problem to be solved
- Solution building blocks
- Protocol flows
- Industry standard implementations
- Host use of feature
- Future developments
Foreword

- Broad participation
  - Standards Committees
    - T10 (SCSI)
    - T13 (ATA)
  - Co-proposers
    - Seagate
    - Toshiba
    - Western Digital

- Abstracted
  - Technology neutral
    - Speak here in terms of HDD
    - Applicable also to (e.g.) SSD
  - Standardized Implementation
  - Replacing earlier proprietary solution protocols
Problem to be solved

- Device reliability
  - Millions of hours of MTBF
  - Large yet limited

- Failure modes
  - Trending towards single element (head/disk) issues
  - Logical to physical mapping may not be knowable a priori (indirection)

- Central value proposition of depopulation
  - ‘Offline’ degraded element
  - Other elements remain in service
Solution building blocks

- Device self-monitoring
  - Background monitoring of each element’s performance
  - Compared against threshold

- Semi-asynchronous signal to host
  - Upon threshold cross – IE on SCSI, DSN on ATA

- Host query of device – GET PHYSICAL ELEMENT STATUS
  - Device returns PHYSICAL ELEMENT HEALTH for each physical element

- Host commands device to remove element
  - REMOVE ELEMENT AND TRUNCATE command
Upon Depopulation command

- Specified physical element is removed (i.e. becomes ineligible for storing data)
  - Reduction of physical capacity
- Device logical capacity truncated to reflect loss of physical capacity
  - Last LBA reduced (e.g. READ CAPACITY returns smaller value)
- Device engages optional initialization
  - E.g. Some implementations may require reformat of logical sectors across physical sectors
Result of Depopulation

- Device ‘returns’ as ‘new’, smaller, good device
- Reads return indeterminate data (until written)
  - Logical to physical mapping may be changed
  - No assumptions about any user data
  - If security consideration, host must ‘clean’
Protocol flows

Host issuing sequence of IO commands

Host issues GET PHYSICAL ELEMENT STATUS

Host parses data, finds outlier, issues REMOVE ELEMENT AND TRUNCATE

Device detects physical element threshold cross

Device returns Informational Exception (WARNING – PHYSICAL ELEMENT STATUS CHANGE)

Device returns parameter data including PHYSICAL ELEMENT HEALTH for each physical element

Device removes element from physical inventory, truncates logical capacity, returns complete
Command processing

- May execute as background processes
  - Depopulate
  - Truncate
  - Initialize (optional)
- Very limited set of commands allowable during processing
  - Most queries (INQUIRY, GET PHYSICAL ELEMENT STATUS, …)
- Host can poll for completion
  - GET PHYSICAL ELEMENT STATUS header
  - Device advertises DEPOPULATION TIME (VPD, IDENTIFY DEVICE data log)
Industry standard implementations

- T10 has incorporated into SBC-4
  - SCSI Block Commands - 4
  - 2016 Nov – current is **sbc4r14**
- T13 has incorporated into ACS-4
  - ATA Command Set - 4
  - 2017 Feb – current is **di529r18**
SCSI Standard SBC-4

- Model: 4.38 Repurposing depopulation
  - Describes mechanism, notification, operations, effects on other commands
- 5.7 GET PHYSICAL ELEMENT STATUS
  - Query command description
- 5.25 REMOVE ELEMENT AND TRUNCATE
  - Operational command
- Annex J Using repurposing depopulation
GET PHYSICAL ELEMENT STATUS

STARTING ELEMENT and ALLOCATION LENGTH allow host to use sequence of commands to iterate across all elements.

FILTER specifies returned list contain: all elements; or only interesting ones.

REPORT TYPE specifies list of: all elements; or only storage elements.

### Table 56 — GET PHYSICAL ELEMENT STATUS command

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### Notes
- **FILTER** specifies the returned list contains: all elements; or only interesting ones.
- **REPORT TYPE** specifies the list of: all elements; or only storage elements.
### Physical element descriptor data

#### Table 59 — GET PHYSICAL ELEMENT STATUS parameter data

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**Bit 0**: (MSB) **Bit 7**: (LSB)

- **NUMBER OF DESCRIPTORS**
- **NUMBER OF DESCRIPTORS RETURNED**
- **IDENTIFIER OF ELEMENT BEING DEPOPULATED**
- **Reserved**
- **physical element status descriptor list**
  - **physical element status descriptor [first]**
  - **...**
  - **physical element status descriptor [last]**

#### Table 60 — Physical Element Status descriptor format

<table>
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**Bit 0**: **Element Identifier**

- **PHYSICAL ELEMENT TYPE**
- **PHYSICAL ELEMENT HEALTH**

**Bit 16**: **Associated Capacity**

- **Reserved**

#### Bit Values

- **01h to 63h**: within manufacturer’s spec limit
- **64h**: at manufacturer’s spec limit
- **65h to CFh**: outside manufacturer’s spec limit
- **FDh**: depopulation error
- **FEh**: depopulation in progress
- **FFh**: successfully depopulated
REMOVE ELEMENT AND TRUNCATE

Element Identifier specifies element to be removed

Requested Capacity specifies logical capacity upon completion.
Zero specifies device shall choose.
If unable to meet, device aborts command.

Table 104 — REMOVE ELEMENT AND TRUNCATE command

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Monitor for additional sense code of WARNING– PHYSICAL ELEMENT STATUS CHANGE

Upon that ASC/Q, issue GET PHYSICAL ELEMENT STATUS

- Parse for physical element health outside manufacturer’s spec limit (65h to CFh)
- Use case dependent: may save data not part of redundancy set

Issue REMOVE ELEMENT AND TRUNCATE

Upon completion, treat as new, somewhat smaller device
SCSI Host - Degraded head identification sequence

Command terminated with Informational Exception

GET PHYSICAL ELEMENT STATUS command

Any Physical Element with Physical Element Health outside manufacturer’s specification limit? (65h to CFh)

Yes

Execute depop

Sense code = 0Bh / 14h (WARNING – PHYSICAL ELEMENT STATUS CHANGE)
Follow on designs

- WD has also prototyped Data Preserving Depopulation
- Allows retention of user data on non-removed elements
  - Split Depopulation, Truncation into separate commands
  - Add Amputation, Regeneration, additional queries to manage LBA holes
- Proposals to T10 & T13 withdrawn
  - Complexity viewed as not warranted at this time
  - Will reintroduce if customer pull
Calls to action

- Implement in your host storage management stack
- Provide feedback on utility and design
  - T10.org
  - T13.org
  - joe.breher@wdc.com
- Desire Data Preserving variant? Let us know!
Backup material

Thank You!
Learning Objectives

- Understand the need for Repurposing Depopulation and its main benefits
- Learn real-life applications of Repurposing Depopulation
- Understand the architecture and design of the Repurposing Depopulation feature
- Understand protocol flows as it is implemented in T10 (SCSI) and T13 (ATA)
- Learn how to apply the benefits of Repurposing Depopulation in your products