What Can One Billion Hours of Spinning Hard Drives Tell Us?

What: Storage Developer Conference
When: September 2016
Who: Gleb Budman, CEO
@GlebBudman
Overview

- Our environment
- How we diagnose “sick” drives
- Drive Reliability Findings
  1. Reliability over time
  2. Enterprise vs. consumer drives
  3. Effects of temperature
  4. Effects of power cycling
- Review and Questions
Introducing Backblaze

B2 Cloud Storage

The lowest cost cloud storage on the planet: $0.005/GB a month. Try it and get the first 10 GB free on us.
Our Environment
Once upon a time… …Storage Pod 1.0
Speed bumps…

…Success too
Backblaze Vaults
How do we diagnose “sick” drives?
Defining a Drive Failure

- The drive will not spin up or connect to the OS.
- The drive will not sync, or stay synced, in a RAID Array (see note below).
- The SMART Stats we use show values above our thresholds.

- Note: Stand-alone Storage Pods use RAID-6. Backblaze Vaults use our own open-sourced implementation of Reed-Solomon erasure coding instead. Both techniques have a concept of a drive not syncing or staying synced with the other member drives in its group.
### SMART attributes we use for failure detection

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Reported by</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMART 5</td>
<td>Reallocated Sectors Count</td>
<td>All</td>
</tr>
<tr>
<td>SMART 187</td>
<td>Reported Uncorrectable Errors</td>
<td>Seagate</td>
</tr>
<tr>
<td>SMART 188</td>
<td>Command Timeout</td>
<td>Seagate</td>
</tr>
<tr>
<td>SMART 197</td>
<td>Current Pending Sector Count</td>
<td>All</td>
</tr>
<tr>
<td>SMART 198</td>
<td>Uncorrectable Sector Count</td>
<td>Seagate</td>
</tr>
</tbody>
</table>
Detection rates of SMART attributes in aggregate

- Number of Backblaze SMART attributes > 0
  - 5: 0.00% (Failed), 10.55% (Operational)
  - 4: 0.01% (Failed), 10.49% (Operational)
  - 3: 0.05% (Failed), 12.56% (Operational)
  - 2: 0.36% (Failed), 24.26% (Operational)
  - 1: 3.87% (Failed), 22.90% (Operational)
SMART attributes for failure detection
Does it matter? You decide.

4.2% 76.7%

Percentage of operational drives with 1 or more of our 5 attributes > 0
Percentage of failed drives with 1 or more of our 5 attributes > 0
Detection rates of Operational vs Failed drives

Percentage of drives with SMART attribute RAW value > 0

<table>
<thead>
<tr>
<th>Drive Status</th>
<th>SMART 5</th>
<th>SMART 187</th>
<th>SMART 188</th>
<th>SMART 197</th>
<th>SMART 198</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>1.1%</td>
<td>0.5%</td>
<td>4.8%</td>
<td>0.7%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Failed</td>
<td>42.2%</td>
<td>43.5%</td>
<td>44.8%</td>
<td>43.1%</td>
<td>33.0%</td>
</tr>
</tbody>
</table>

1) Operational drives as of July 31, 2016
2) Failed drives as of one day prior to failure
Correlation of stats used for failure detection

<table>
<thead>
<tr>
<th></th>
<th>SMART 5</th>
<th>SMART 187</th>
<th>SMART 188</th>
<th>SMART 197</th>
<th>SMART 198</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMART 5</td>
<td>1</td>
<td>0.034</td>
<td>0.026</td>
<td>0.064</td>
<td>0.043</td>
</tr>
<tr>
<td>SMART 187</td>
<td>0.034</td>
<td>1</td>
<td>0.007</td>
<td>0.025</td>
<td>0.033</td>
</tr>
<tr>
<td>SMART 188</td>
<td>0.026</td>
<td>0.007</td>
<td>1</td>
<td>0.000</td>
<td>0.006</td>
</tr>
<tr>
<td>SMART 197</td>
<td>0.064</td>
<td>0.025</td>
<td>0.000</td>
<td>1</td>
<td>0.808</td>
</tr>
<tr>
<td>SMART 198</td>
<td>0.043</td>
<td>0.033</td>
<td>0.006</td>
<td>0.808</td>
<td>1</td>
</tr>
</tbody>
</table>

SMART 5 - Reallocated Sectors Count
SMART 187 - Reported Uncorrectable Errors
SMART 188 - Command Timeout
SMART 197 - Current Pending Sector Count
SMART 198 - Uncorrectable Sector Count
What other SMART stats have we looked at to see if they can help predict drive failure?
SMART 189 – High Fly Writes

- Detects when a recording head is flying outside its normal range of operation.
- Adds to counter each occurrence.
- Seagate only in our dataset.

<table>
<thead>
<tr>
<th></th>
<th>Failed Drives - 47.0%</th>
<th>Operational Drives - 16.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome:</td>
<td>Needs more study, its more about frequency and distribution of occurrence than quantity.</td>
<td></td>
</tr>
</tbody>
</table>
SMART 10 – Spin-Retry Count

- The count of retries of each spin start attempt after the initial failure.
- Only found in some HGST and Toshiba drives.

<table>
<thead>
<tr>
<th>Failed Drives</th>
<th>1.48%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Drives</td>
<td>0.07%</td>
</tr>
</tbody>
</table>

Outcome: In our case we don’t power cycle drives much, so we don’t see this error. But, could be a sign of impending failure.
So, what is the failure rate of drives?
Drive Stats

- Drives in operation: 68,877 as of July 31, 2016
- Number of failures: 4,794
- Operational Drive Hours: > 1Billion
- 6.9% of our drives have failed, BUT…
Annualized Failure Rate

AFR is just 3.89%

$$AFR = \frac{100 \times \text{drive-failures}}{(\text{drive-days}/365)}$$
Drive Failure Rates Over Time

The bathtub curve

The curve in reality
Are enterprise drives more reliable?
Enterprise versus Consumer drives at Backblaze

<table>
<thead>
<tr>
<th></th>
<th>Enterprise Drives</th>
<th>Consumer Drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive-Years of Service</td>
<td>368</td>
<td>14,719</td>
</tr>
<tr>
<td>Number of Failures</td>
<td>17</td>
<td>613</td>
</tr>
<tr>
<td>Annualized Failure Rate</td>
<td>4.6%</td>
<td>4.1%</td>
</tr>
</tbody>
</table>

At Backblaze the failure rate of our enterprise drives is actually higher than that of our consumer drives!
Drives fail when they’re too cold, too hot, or just right?
Operational Drives by Temperature

- 77°F: N=68,877
Failed Drives versus Operational Drives by Temperature
SMART vs. Temperature

Does temperature correlate to our detection stats?

<table>
<thead>
<tr>
<th>SMART 194 Temperature</th>
<th>SMART 5</th>
<th>SMART 187</th>
<th>SMART 188</th>
<th>SMART 197</th>
<th>SMART 198</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.015)</td>
<td>0.005</td>
<td>(0.019)</td>
<td>(0.008)</td>
</tr>
</tbody>
</table>
Is power cycling drives bad?
SMART 12 – Power Cycle Count

- The count of full hard disk power on/off cycles.
- We only power cycle drives when there’s a problem with the Storage Pod they are in.

<table>
<thead>
<tr>
<th>Description</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average number of times the Failed Drives were power cycled</td>
<td>27.7</td>
</tr>
<tr>
<td>The average number of times the Operational Drives were power cycled</td>
<td>10.2</td>
</tr>
</tbody>
</table>
Review

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- How we diagnose “sick” drives
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