Touching the Heart of Storage

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Outline

• Touch rate and response time
• Customer needs and storage technologies
• Moving from hierarchy to applications
• HDDs
• Flash memory
• Archiving—tape and optical
• Storage system design
• Conclusions
Definitions

• *Touch rate* is defined as the portion of the total capacity of a system that can be accessed in a given interval of time.
  
  – Touch Rate/Year

\[
\text{Touch}/Y = \frac{\text{ObjectSize(\text{MB})}}{\text{ResponseTime(s)} \times \text{Capacity(\text{PB})} \times 0.0315}
\]

• The *response time* is the time to complete an IO operation, including the transfer of data and restoring the system for a subsequent IO operation. The response time is therefore a function of the IO object size as well as the speed of ancillary support operations.
Touch rate versus response time indicating various types of uses

Touch Rate vs. Response Time

- **More Accessible**
- **Increasing S/TB**
- **Fast enough for disk stack**
- **Limit of human response tolerance**
- **Faster**

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Minimum Latency Requirement

Storage Devices Developments

• Hard disk drives
  – Cold Storage Drives with SMR and He-filled drives promise 10 TB drives in 2015
  – Hybrid HDDs, as thin as 5 mm
  – New interfaces—Kinetic from Seagate, Thunderbolt 3, USB 3.1

• Flash Memory
  – Samsung 3D TLC flash (1 TB SSDs)
  – 15-16 nm flash production in 2015
  – SanDisk—up to 16 TB SSD by 2016
Emerging Memory Technology

- NVM will save power
- Persistent memory enables memory sharing (RDMA)
- Embedded NVM technology can lead to “logic-in-memory architecture”

STT MRAM market could exceed $2 B by 2019

2014 Emerging NVM Report and Their Manufacture, Coughlin Associates
Memory/Storage Hierarchy

- Qualitative trade-offs between volatile (and non-volatile) memory and non-volatile storage technology
  - costs to store data ($/TB)
  - performance of the storage technology (IOPS) or data rates).
Digital storage technologies regions overlaid on the Touch Rate/Response Time chart

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Touch/Y and response time for 100% random IO in a 4 TB capacity HDD
The tyranny of density (High Perf. HDDs)

- In HDDs, the increase in capacity with areal density reduces the touch rate, since HDDs generally increase their capacity faster than their data rate.
- Other technologies, e.g. flash, can thus provide high touch rates and displace these HDDs.
- But the same trend is happening to flash memory, which may be displaced by some other NVM in time.

- TW increases don’t increase data rate and thus reduce touch rates
- Likewise increasing # of disks in a HDD reduce touch rates
Banded HDD Unit Projections

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HDD application unit projections

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Ent. SSDs, perf. HDDs and capacity HDDs
Flash DWD limits in a touch rate chart

PCle Flash Touch Rate vs. Response Time

Touch/Y

Response Time (s)

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Projections for HDD and flash memory capacity shipments

Annual Shipped Storage Capacity (Exabytes)

- HDD
- SSD

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4 TB capacity HDD data event horizon

Touch Rate vs. Response Time Event Horizon

- **1TB**
- **64GB**
- **4GB**
- **256MB**
- **16MB**
- **Hi IOPS**
- **1MB**
- **Transaction**
- **64kB**
- **Cap. HDD**
- **Near Line**
- **12 T/Y Event Horizon**
- **SemiActive**
- **ColdActive**
- **InActive**

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Storage Devices Developments (2)

- Magnetic data tape
  - LTO roadmap to gen 10 with 48 TB
  - IBM 10 TB
  - Object based tape
- Blu-ray WORM
  - 300 GB Discs by 2015, 500 GB by 2017 and 1 TB by 2019
  - 12 disc cartridges
Comparison of archive storage
HDD-Flash tiering/caching touch rate chart

HDD-Flash Tiering Touch Rate vs. Response Time

- 16TB
- 1TB
- 64GB
- 4GB
- 256MB
- 16MB
- 1MB

Touch / Y

- InActive
- ColdActive
- SemiActive
- Near Line
- Hi IOPS

1MB Segment

Response Time (s)

- 100,000s
- 10,000s
- 1,000s
- 100s
- 10s
- 1s
- 100ms
- 10ms
- 1ms
- 100μs
- 10μs

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Tape-HDD tiering touch rate chart

Tape-HDD Tiering Touch Rate vs. Response Time

- **InActive**
- **LTO6 1 limit**
- **4GB Segment**
- **64GB Segment**
- **1TB Segment**
- **1TB**
- **64GB**
- **4GB**
- **256MB**
- **16MB**
- **Cap. HDD**
- **SemiActive**
- **ColdActive**
- **Hi IOPS**
- **Transaction**
- **Near Line**
- **64kB**
- **4kB**

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Conclusions

• A new metric comparing touch rate and response time can be used to characterize storage devices and in system design

• We gave examples with HDDs, flash memory, tape and optical disc on how different storage provides different advantages depending upon the application
References


• Touch Rate: A metric for analyzing storage system performance, Steven Heltzer and Tom Coughlin, 2015, http://www.tomcoughlin.com/techpapers.htm
Thanks