The Looming Need for Molecular Storage

How to store Yottabytes on a budget

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How to we store Exabytes of Data?

- Many kilometers of Storage Racks, in hundreds of Datacenters.
- Hundreds of MW of power.
The vast majority of data is moving to the Cloud

- In 2010’s HDD shifted from Consumer to DC. By 2030 almost all HDD will be nearline in the cloud.
- Underlying data growth signal is unwavering, and projects to over 7 ZB per year by 2030 <not shown>
- Data CAGR about 40%
- HDD Capacity CAGR < 20%
Storage Efficiency Improvements 2008 to 2022

- 2006: 500GB HDD, 3 Replica, 4 HDD/Server
- 2008: 1 TB HDD, 3 Replica, 12 HDD/Server
- 2021: 20 TB HDD, <1.3 Replica, 80+ HDD/Server

> 99.5% reduction in online storage cost over 15 years
Efficiency Improvements for HDD continue… but.

- HDD Suppliers are shifting to MAMR and HAMR
- Only HAMR has legs to 60 TB+
- HAMR might run out of steam around 100TB
- Optimistically if we assume HDD growth to 230TB+, we will require 5% of current US Power capacity to be dedicated to spinning HDDs by 2042, and 60% by 2050

Something has to change:

- Data growth has to slow.
- Power Generating capacity needs to vastly increase.
- Data Storage Technology needs to change.
Azure Storage + MSR researching new media types

- Data storage in DNA
- Data storage in Silica Glass
- Holographic Data storage in Sodium Niobate crystals
Molecular Storage the Panacea for density

- Highest Storage Density of Any Technology
- DNA Storage Alliance is building standards around DNA storage.
  - First commercial products based on data storage in molecules.

- Problem: Read and Write Rates

- Electronic Molecular interface… based on medical research

- Can we build fast Molecular Storage?
Where is most of Humanity’s Data Stored?

- HDD industry shipped 1ZB for the first time in 2021
- 1,000,000,000,000,000,000,000 bytes \(10^{21}\)
- Power if on 20TB HDDs @10W each would be: 50 Million HDDs and 500MW.
- What about Human Brains?
- 8 Billion Humans
- 2.5PB per brain (estimated)
- Power @ 20W per brain: 160GW
- 2 Yottabytes in Brains (About 1000x data stored on HDD)
Compute Evolution

Analytic Engine
Designed 1820
Metal Gears
Mechanical

ENIAC
1945
Vacuum Tubes
Crystal Diodes

EDSAC
1949
Thermionic Valves

1955 Burroughs
Atlas
Transistors

1957
Univac
Transistors

Intel 4004: First computer on an IC
1971

Intel Xeon SPR
2021, 100,000,000x
improvement over 4004
Storage needs a Platform shift for YottaScale (2042)

Today’s Storage Platforms:
- Magnetic Charge (Tape/HDD/Core Memory)
- Electric Charge (Flash, RAM)
- Optical
- Holographic (Lithium Niobate and Lasers)
- Molecular (DNA)

Future do we need fast Molecular Storage?
- DNA based?
- Can we build the toolchain for molecular machines?
What’s next?

- Research in Molecular Simulation is Ramping:
  - Alpha Fold - Google
  - AI4Science (announcement) - Microsoft
  - Medical Research

- Resolving the Molecular / Electronic interface is critical

- Possibility to leverage patterns from Biology? Molecular Machines?

- YottaScale 2042(ish), XanoScale 2063(ish)
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