SAS Rules the Data Center

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President, SCSI Trade Association

Director of Marketing, SSD and Storage Solutions, Toshiba Memory America, Inc.
SAS Remains Primary Enterprise Storage Interface

SAS Infrastructure Enables >64% of Enterprise Storage Drives and >80% of Enterprise Storage Capacity thru 2023

Source: IDC, May 2019
SAS Enterprise Architecture

Storage Area Network

Network

Servers

Ethernet or FC switches

SAS/SATA Storage
SAS Enterprise Architecture: A Closer Look

Fibre Channel or Ethernet to a SAN

Network

SAS HBA if DAS to a server

SAS Expander

SAS IOC

SAS Expander

SAS IOC
OCP Hyperscale Design Example #1

Wiwynn Honeybadger 12Gb/s SAS Storage Server

- Designed to support up to 30 SAS HDDs in a 2U chassis
- Based on Facebook’s Open Vault Storage Hardware specification
OCP Hyperscale Design Example #2

Wiwynn Bryce Canyon 12Gb/s SAS Storage Server

- Designed to support up to 72 hot-pluggable SAS HDDs
- Based on Facebook’s Storage System specification
OCP Hyperscale Bryce Canyon Design

Drive Plane Board

IO Module

- 25/50 Gb NIC
- BMC
- M.2
- M.2

Compute Module

- Memory
- CPU
- Boot SSD

- x4 PCIe Gen 3
- x4 PCIe Gen 3
- x8 PCIe Gen 3

Storage Controller Card

- SAS IOC
- SAS Expander

- x8 12Gb/s SAS

IO Module

- 25/50 Gb NIC
- BMC
- M.2
- M.2

- x4 PCIe Gen 3
- x4 PCIe Gen 3
- x8 PCIe Gen 3

- 36 HDDs

36 HDDs

- x36 12Gb/s SAS / 6Gb/s SATA

Source: FB.engineering.com
Data Center Storage Applications

- SaaS
- Social Media
- Cloud Storage
- Web Hosting
- Content Delivery
- Application Delivery
- Surveillance
- Transactional
- Gaming
- Online Banking
- Financial Trading

Write Intensive

Read Intensive

Low Performance

High Performance
24G SAS takes performance and reliability to new levels.
SAS Infrastructure Supports Diverse Workloads

<table>
<thead>
<tr>
<th>Application/Use Case</th>
<th>Workload Characteristic</th>
<th>Storage Requirements</th>
<th>Key Performance Metrics</th>
<th>Storage Performance Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Learning</td>
<td>Large highly parallel reads</td>
<td>Direct Attached SATA</td>
<td>Sm SR Lg SR Sm SW Lg SW Sm RR Lg RR Sm RW Lg RW</td>
<td>Ability to process large amounts of data, mostly read operations</td>
</tr>
<tr>
<td>Sensor, Radar &amp; Signal Processing</td>
<td>Small highly parallel writes</td>
<td>Direct Attached SAS</td>
<td>Sm SR Lg SR Sm SW Lg SW Sm RR Lg RR Sm RW Lg RW</td>
<td>Ability to ingest large amounts of unprocessed sensor/signal inputs</td>
</tr>
<tr>
<td>Financial Trading</td>
<td>Very small parallel writes &amp; checkpointing</td>
<td>Direct Attached SAS</td>
<td>Sm SR Lg SR Sm SW Lg SW Sm RR Lg RR Sm RW Lg RW</td>
<td>Minimize logging time &amp; checkpoint operations</td>
</tr>
<tr>
<td>Transactional Databases</td>
<td>High intensity random reads &amp; writes</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR Lg SR Sm SW Lg SW Sm RR Lg RR Sm RW Lg RW</td>
<td>Maximize random I/O performance</td>
</tr>
<tr>
<td>File + App Services</td>
<td>80% Read/20% Write (OLTP), Varying sizes</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR Lg SR Sm SW Lg SW Sm RR Lg RR Sm RW Lg RW</td>
<td>Manage a high number of small random requests &amp; effective cache utilization</td>
</tr>
<tr>
<td>OLAP &amp; ETL (Business Intelligence)</td>
<td>Large reads followed by ad-hoc queries</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR Lg SR Sm SW Lg SW Sm RR Lg RR Sm RW Lg RW</td>
<td>Provide high read bandwidth for quick ETL’s &amp; high IOPs for fast business queries</td>
</tr>
</tbody>
</table>
## SAS Infrastructure Supports Diverse Workloads (cont’d)

<table>
<thead>
<tr>
<th>Workload</th>
<th>Workload Characteristic</th>
<th>Storage Requirements</th>
<th>Key Performance Metrics</th>
<th>Storage Performance Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Imaging</td>
<td>Large sequential reads and writes</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR</td>
<td>Sm SW</td>
</tr>
<tr>
<td>Content Management</td>
<td>Large sequential reads/writes, meta-data indexing, random content access</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR</td>
<td>Sm SW</td>
</tr>
<tr>
<td>Big Data</td>
<td>Large sequential reads and writes</td>
<td>Direct Attached SATA/SAS</td>
<td>Sm SR</td>
<td>Sm SW</td>
</tr>
<tr>
<td>Software Defined Storage</td>
<td>Application dependent. Primarily random workloads</td>
<td>Direct Attached SATA/SAS</td>
<td>Sm SR</td>
<td>Sm SW</td>
</tr>
<tr>
<td>Backup/Disaster Recovery</td>
<td>Large sequential reads and writes</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR</td>
<td>Sm SW</td>
</tr>
<tr>
<td>Analytics / Data Mining</td>
<td>Highly parallel random reads</td>
<td>RAID: SATA/SAS</td>
<td>Sm SR</td>
<td>Sm SW</td>
</tr>
</tbody>
</table>

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24G SAS Highlights

Physical Layer Enhancements

- **2.4 GB/s effective single-lane bandwidth (22.5 Gbaud rate)**
  - Higher throughput and IOPs performance

- **Enhanced 20-bit Forward Error Correction (FEC)**
  - More robust data reliability and connectivity

- **SAS-4 transmitter training algorithm**
  - Better signal integrity via continuous optimal signal tuning

Protocol & Block Level Enhancements

- **Fairness enhancements**
  - Performance consistency across large and mixed protocol topologies

- **Storage intelligence and persistent connections**
  - Improves SSD efficiency, latency, and QoS

- **SMP priorities**
  - Determines priority for management-class communications

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SAS Innovations in HDD and SSD Technologies

Storage media is ever-changing to increase IOPS and capacity

- HAMR
- MultiLink
- Storage Intelligence
- SMR
- TDMR
- SSHD
- Helium
- Multiple Actuator
- MAMR

SAS takes advantage of these new drive technologies
SAS Technology Roadmap

- **First End-User Products**
- **12Gb/s SAS**
- **24G SAS**
- **48G SAS**

Timeline:
- **2008**
- **2009**
- **2010**
- **2011**
- **2012**
- **2013**
- **2014**
- **2015**
- **2016**
- **2017**
- **2018**
- **2019**
- **2020**
- **2021**
- **2022**
- **2023**
- **2024**
- **2025**
- **2026**
- **2027**
- **2028**
- **2029**

Key Events:
- **First Plugfest (leading edge)**
- **2009**: First End-User Products
- **2011**: 6Gb/s SAS
- **2013**: 12Gb/s SAS
- **2017**: 24G SAS
- **2020**: 48G SAS
Summary Comparison of a Typical Drive Deployment

<table>
<thead>
<tr>
<th></th>
<th>SAS</th>
<th>NVMe™</th>
<th>SATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance (IOPS, GB/s)</td>
<td>Better (x1 lane)</td>
<td>Best (x4 lanes)</td>
<td>Good</td>
</tr>
<tr>
<td>Performance (Read Latency ¹)</td>
<td>Better</td>
<td>Best</td>
<td>Good</td>
</tr>
<tr>
<td>Scalability</td>
<td>Best</td>
<td>Good (*Better w/ NVMe-oF™)</td>
<td>Better (SAS infrastructure)</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Best (SAS, SATA, HDDs, SSDs)</td>
<td>Good (SSDs)</td>
<td>Better (SSDs, HDDs)</td>
</tr>
<tr>
<td>Manageability and Hot Plug ²</td>
<td>Best (most mature)</td>
<td>Good (recent spec)</td>
<td>Better (SAS infra)</td>
</tr>
<tr>
<td>Reliability</td>
<td>Best</td>
<td>Better</td>
<td>Good</td>
</tr>
<tr>
<td>System cost</td>
<td>Higher</td>
<td>Highest (performance premium)</td>
<td>Lowest</td>
</tr>
<tr>
<td>Roadmap future</td>
<td>Long-term</td>
<td>Long-term</td>
<td>Limited</td>
</tr>
</tbody>
</table>

¹ Latency includes OS, driver, HBA (if required) and flight time, media access times not included
² includes surprise hot plug and managed hot plug
SCSI Command Set is Pervasive

- SCSI protocol is a highly robust command set used in high-performance workstations, servers, and storage appliances
- Industry-proven – SCSI command set implemented by other storage interfaces, including:

  - 24G SAS (and all previous generations of SAS)
  - Fibre Channel
  - USB Mass Storage Class
  - Infiniband
  - Ultra320 SCSI (and all previous generations of parallel SCSI)
  - iSCSI
  - IEEE 1394 (Firewire)
24G SAS Ecosystem Readiness in 2020

- Ecosystem is on track for SAS-4 production readiness in 2020
  - SAS-4 analyzers have been sampling since last year

- Cables and connectors: both existing and new form-factors ready for 24G SAS

- SAS-4 controllers and expanders aligned with upcoming Gen4 platform launches

- New HDD/SSD capabilities to intersect with 24G SAS ecosystem
  - MultiLink SSDs
  - Hybrid SMR
  - Multiple Actuator
  - HAMR / MAMR