Today’s Presenters

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Agenda

- Who is STA?
- Recap of “SAS 101” Webinar
- Deciphering the Layers of the SAS Specification
- Storage Media Evolutions
- Usage Models
- Legacy Features and Attributes
- New Features with 24G SAS
- Summary
STA At-a-Glance

- Formed over 20 years ago as industry alliance of key ecosystem partners
- STA markets and promotes Small Computer System Interface (SCSI) and Serial Attached SCSI (SAS)
- We welcome all to join STA to promote and contribute to the evolution of SAS

Learn more at [www.scsita.org/content](http://www.scsita.org/content)
SCSI T
rade Association™

◆ SCSI is the Foundation of Numerous Storage Interfaces

◆ SAS Spans the Storage Spectrum
◆ Topology Examples – DAS, Server Storage, Cloud Storage, External Storage
◆ Applications of SAS in the Data Center
◆ On-demand at: https://www.brighttalk.com/webcast/17447/359611/sas-101-the-most-widely-deployed-storage-interface
Specifications/Enhancements Timeline

**Physical Layer**
- **SAS-2**
  - 6Gb/s link rate
  - Zoning
  - Managed cables
  - Power management
  - Cable management
- **SAS-2.1**
- **SAS-3**
  - 12Gb/s link rate
  - Decision Feedback Equalization (DFE)
  - Transmitter training
  - Crosstalk
- **SAS-4**
  - 22.5 GBaud
  - 20-bit Forward Error Correction
  - 128b/130b encoding, packets
  - Insertion loss specifications
  - SlimSAS and MiniLink connectors

**SAS Protocol Layer**
- **SPL-2**
  - Transmitter training
  - Optical cables
- **SPL-3**
  - Persistent connections
  - Power primitives
- **SPL-4**
  - SAS packets
  - Fairness
  - Active PHY Transmitter Adjustment (APTA)
- **SPL-5**
  - Re-timers
  - Wide ports
  - Interleaving
  - Obsolete muxing

**SCSI Command Layer**
- **SPC / SBC / SAM / SES / SAT**
  - SCSI evolutions for ZBC, etc.
  - Rebuild assist for SSDs
- **ZBC**
  - Support SMR
  - Zoned blocks
  - Zoned format
- **ZBC-2**
  - Dynamic zones
  - Sanitize rules
Storage media is ever-changing to increase IOPS and capacity and to provide lowest cost per GB

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Data Everywhere (and Every Way)

THE INTERNET OF THINGS

Social Media Icons:
- Facebook
- Instagram
- YouTube
- Twitter
- TikTok
- LinkedIn
- Snapchat
- WhatsApp
- Pinterest
Scalable, Flexible Storage Ecosystem

Performance (IOPS)

- Hot Tier
  - SAS SSDs
  - SAS HDDs
  - SATA SSDs

Scalability

- Warm Tier
  - Cascaded JBODs (with SAS expanders) of Nearline SAS HDDs

Large-scale, low power, low cost, high capacity ($/GB)

- Cold Tier
  - Cascaded JBODs (with SAS expanders) of SATA SMR HDDs

June 16, 2020
24G SAS Highlights

PHY Enhancements

- 2.4 GB/s effective single-lane bandwidth (22.5 Gbaud rate)
- Enhanced 20-bit Forward Error Correction (FEC)
- SAS-4 transmitter training algorithm

More robust data reliability and connectivity
Better signal integrity via continuous optimal signal tuning

Protocol & Block Enhancements

- Fairness enhancements
- Storage intelligence and persistent connections
- SMP priorities

Performance consistency across large and mixed protocol topologies
Improves SSD efficiency, latency, and QoS
Determines priority for management-class communications
Challenges of 24G SAS Interconnect

- **Goal to retain the same cable and backplane trace lengths as previous SAS generations**
  - 6m cable including 2 connectors
  - 18” backplane including 2 connectors

- **24G SAS creates new signal integrity challenges**
  - Crosstalk between adjacent traces
  - Insertion loss distortion (ILD)

- **Resulting in bit errors during transmission**
  - SAS supports $1 \times 10^{-15}$ bit error rate (BER)
  - Typical 30dB channel loss using common PCB materials would result in $1 \times 10^{-9}$, which is 1 million more bit errors than specification

- **Errors are detectable and retry events eliminate data loss, but performance is impacted when a bit error makes it through to the protocol layer.**
Solving transmission challenges

- Tune each interconnected transmitter and receiver equalization so they are optimized for the channel
  - Links tune each other at initial power up and speed negotiation (SAS-3 added this)
  - Links make fine tuning equalization adjustments during normal operation to adapt for environmental and other changes

- Introduce Forward Error Correction (FEC)
  - A symbol code that provides positional and error detection information for a packet
  - Add an FEC stage after the receiver and before the data is sent to the protocol layer
  - Detects and corrects errors, so the effective bit error rate is improved to $10^{-15}$

- Partition transactions into packets
  - Enables error checking on smaller dataset
  - Reduces buffering, which reduces latency
Reed Solomon error correction algorithm is used for 24G SAS

Ethernet also uses the Reed Solomon algorithm
- Ethernet uses large packets and has long latency
- Ethernet is allowed to drop packets
- RS(544, 514,10) = 5440 bits per packet
- Adds ~100ns for FEC processing

24G SAS uses RS(30,26,5)
- 5 = symbol size in bits
- 26 = payload size in symbols (5x26= 130bits)
- 30 = total packet size in symbols (5x4= 20-bit FEC code overhead)
- Adds FEC processing overhead ~4nS

For an input BER of 1e-9, FEC correction results in better than 1e-15 BER
- 1 MILLION times improvement!
Inline Transmitter Training without Resetting Link

- What Mechanism will be used to initiate APTA mode?
  - SAS-4 PHYs detect bit-errors during normal operation
  - Requests Management Application Layer start APTA

- SAS-4 PHYs are *required* to support APTA
  - Exceptions: Optical & Active Cable links
Summary of 24G SAS Enhancements

- Solved electrical signal integrity challenges for 24G SAS to double effective bandwidth from 12Gb/s SAS while maintaining same cable lengths for existing topologies
- Tweaked protocol to improve response time and fairness in large-scale systems so that devices at the end of long pipeline are not swamped by transactions closer to the hosts – fairness and persistent connections are two such features.
- Developed storage intelligence to optimize SSD performance
- 24G SAS intersects with PCIe-Gen4 (16GT/s) and PCIe-Gen5 host systems, where the bandwidth of 24G SAS can be fully utilized.
- STA has already hosted one 24G SAS plugfest, with more to follow as the ecosystem becomes ready for greater bandwidth to service more storage devices in large scale systems.
Key Takeaways

- The architecture of SAS is optimized for flexibility
- SAS addresses the changing demands of Storage
- SAS continues to innovate around the reliability of Storage
Questions?
Thank You!

For more information, go to:

www.scsita.org/content
https://www.t10.org/

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