EVERYTHING YOU WANTED TO KNOW ABOUT STORAGE
BUT WERE TOO PROUD TO ASK
Part Aqua
Storage Controllers

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SNIA-At-A-Glance

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Controllers!

- So many things to control, so little time!

UP, UP, DOWN, DOWN, LEFT, RIGHT, LEFT, RIGHT, B, A, STORAGE START!
Why Controllers?

- When we talk about “Controllers,” what do we mean?
  - Do DevOps people talk about controllers the same way networking people do? Storage people? Is a domain controller the same thing as a storage “fault domain”?

- What, exactly, do “Controllers” control?

- What happens when you have multiple controllers? Are they required?
  - Are I/O controllers the same thing as disk controllers? If not, do you need both?
Goal of This Webinar

- Introduce the concept of storage controllers
- Illustrate how controllers work in various contexts
- Provide examples of different types of storage controllers
  - Hardware, software, logical, media, protocol
- Clarify some of the aspects of how controllers work in their respective contexts
Agenda

- Introduction
- Storage Controllers 101
- SCSI Controllers
- Fibre Channel Controllers
- NVMe Controllers
- Networking SDN Controllers and Storage SDS Controllers
- Summary
Storage Controllers 101

Craig Carlson
What is a Storage Controller

Controller - A logical or physical entity that manages or directs the flow of data between two entities

A Storage is controller is the device that converts between OS storage commands on the system bus to the storage device

A controller also resides on the storage device to manage storage media
Storage Controller Functions

OS sends commands to storage device

Controller Access Host
Memory As Needed

Controller provides command response and data to Host

Storage Device Hardware/Software
Convert to storage interface and protocol

Controller communicates with storage device in its native interface and protocol
Front-end vs. Back-end controller

Front-end controller handles tasks from the host OS

Back-end controller controls access to the storage media in the storage device
Controllers typically access host memory through a Scatter Gather List (SGL)

- For data writes, the SGL tells the controller the memory to read from
- For data reads, the SGL tells the controller the memory to write the received data to
- Performed by Direct Memory Access (DMA) to/from card
Many times, controllers use Hardware Offload to process commands

- Provides a hardware accelerated path for routine command operations
  - Non-routine events such as error processing still done in software or firmware

- Advantages include:
  - Lower latency for command processing
  - Potential lower power usage
  - May be able to offload processing from the host CPU
Controller processes OS commands to the Native Storage Protocol, these could be one of:

- SCSI
- NVMe
- FICON
- SATA
- NFS
Native Interface

Controller sends commands on the native interface used for a particular storage system, these could be:

- Fibre Channel
- SAS
- Ethernet
- SATA
- And many others
Key Takeaways

- “Controller” can mean different things depending upon context
- Storage controllers can be an interface between devices, can manage physical devices and media, and/or handle I/O
- Controllers may support one or more storage protocols
SCSI Controllers

John F. Kim
Adapter that manages connections to SCSI devices
- Connect to hard/flash/optical drives, scanners, etc.
- E.g., SAS host bus adapter (HBA)
- Chip on motherboard or add-in PCIe card

Or… controller within the SCSI device
- Responds to SCSI commands
- Talks with SCSI controller adapter

Network adapters can carry SCSI commands
- But are not themselves SCSI controllers
Host OS sends SCSI commands to SCSI Controller Adapter

SCSI Controller or Host Bus Adapter (HBA) converts SCSI commands from Host OS to physical signals sent to the SCSI device

Device SCSI controller responds to signals from the SCSI Controller Adapter

SCSI Device
Defining SCSI

- **SCSI = Small Computer Systems Interface**
  - Standardized command set
  - Different physical connections

- **Physical Connection Options**
  - Parallel SCSI (1981)
  - Other: SRP, iSER, SCSI on USB
SCSI Controller Use Case

Local SCSI

Server

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<thead>
<tr>
<th>SAS HBA</th>
<th>HBA or NIC</th>
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<td>HDD/SSD</td>
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OS sends SCSI commands

Local SCSI Devices (DAS)

Networked SCSI

Storage System Controller

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Ethernet, Fibre Channel, or other network

SCSI commands

SCSI Commands

SCSI responses
SCSI Controller Adapter Examples

- **PCle card**
  - Or chip on motherboard

- **SAS or SATA connectivity**
  - Some models do RAID
  - Some also support NVMe
  - SAS expander allows more than 4 devices per connector
Key Takeaways

- “SCSI Controller” means the SCSI adapter (HBA)
- Can send SCSI commands over different connections
  - Fibre Channel, Ethernet, SAS, InfiniBand, USB, etc.
- Local SCSI (DAS) uses SCSI devices
- Networked SCSI storage might not use SCSI devices
  - Storage controller can translate SCSI commands
FC Storage Controllers

Craig Carlson
Tasks of an FC Controller

- Provide Discovery of devices attached to FC Fabric
  - Accessed through the FC Name Server
- Provide access to the FC Management Server
  - Allows access to zoning configuration and other management tasks
- Process commands and provide HW offload
  - Many FC controllers provide HW offload
- Provide interface to the FC Physical transport
  - 64GFC or other speeds
FC Protocol stack

- Multiple protocols supported

- SCSCSI Host Driver
  - FICON Host Driver
  - NVMe Host Driver (Transport Independent)
  - TCP/IP Stack

- FICON Layer
  - NVMe-oF Fabric Transport Services
  - IP over FC

- FCP

- FC or FCoE Fabric

IHV = Independent Hardware Vendor
Most recently supported protocol – NVMe over Fabrics
- Defined by the FC-NVMe project
  - First version completed end of 2016
- Now working on second version – FC-NVMe-2
  - Main item is to define Enhanced Error Recovery
Traditional Protocols

- Long time storage protocol support for
  - SCSI
    - Supported since 1994
  - FICON
    - Supported since 1996
FC Controller Tasks

SCSI, FICON, or NVMe commands sent from OS

FC Lookups via Nameserver are performed, commands converted to FC and sent to Storage Device

Back-end controller receives FC frames and forwards commands to storage devices

FC frames are sent on native FC or FCoE
Key Takeaways

- Fibre Channel has supported SCSI and FICON since mid nineties
- NVMe over FC is the newest addition
- Multiple storage protocols can be supported at the same time on a single port
NVMe Controllers

Peter Onufryk
NVMe Controllers

- **NVMe Controller**: The logical interface between a host and an NVM subsystem.
- **NVMe-MI Management Controller**: The logical entity that manages one or more NVMe Storage Devices.
- **NVMe SSD Controller**: A physical component used to implement an NVMe SSD.
An NVMe controller is the logical interface between a host and an NVM subsystem

- Implements one Admin Submission Queue and Completion Queue
- Implements one or more I/O Submission Queues and Completion Queues
- Processes commands submitted on a Submission Queue and posts a Completion on a Completion Queue
- When PCI Express is used as the transport, then a controller is a PCI function
  - PCI Function, SR-IOV Physical Function, or SR-IOV Virtual Function
- May expose non-volatile memory storage medium to a host through one or more namespaces
A dual ported NVMe Storage Device contains an NVM subsystem with two controllers.

Each host is associated with its own independent controller:
- Independent Admin Submission and Completion queue
- Independent I/O queues
- Independent command processing
An NVMe Storage Device that supports PCIe SR-IOV has one controller for the Physical Function (PF) and one controller for each Virtual Function (VF).

Each virtual machine and the hypervisor is associated with its own independent controller:

- Independent Admin Submission and Completion queue
- Independent I/O queues
- Independent command processing
NVMe Specifications

- **NVMe specification**
  - NVMe architecture and command set
  - NVMe over PCIe transport

- **NVMe-oF specification**
  - Extends NVMe architecture and command set to general interconnects
  - NVMe over RDMA transport

- **NVMe-MI specification**
  - Architecture and command set for out-of-band management of NVMe Storage Devices
NVMe-MI Out-of-Band Management

- Out-of-Band Management – Management that operates with hardware resources and components that are independent of operating system control

- Management Controller
  - Sometime referred to as a Baseboard Management Controller (BMC)
  - Management Responsibilities
    - Inventory
    - Configuration
    - Monitoring
    - Change Management
NVMe-MI Protocol Layering
NVMe SSD Controller - A physical component used to implement an NVMe SSD
Internals of an NVMe SSD Controller

- PCIe Interface
- NVMe Queueing Interface
- Command Processing & Internal Buffering
- ECC
- DRAM Interface
- Flash Interface
- NAND Flash Channels
- DRAM
Key Takeaways

This section shows examples of how different controllers can work in concert to provide holistic functionality in a system.
SDN Controllers

Chad Hintz
What is SDN you ask!
Basic Definitions

- An SDN controller is an application in software-defined networking (SDN) that manages flow control to enable intelligent networking. SDN controllers are based on protocols, such as OpenFlow, that allow servers to tell switches where to send packets.
  - Source: [https://searchsdn.techtarget.com/definition/SDN-controller-software-defined-networking-controller](https://searchsdn.techtarget.com/definition/SDN-controller-software-defined-networking-controller)

- In the SDN architecture, the control and data planes are decoupled, network intelligence and state are logically centralized, and the underlying network infrastructure is abstracted from the applications.
  - Source: [www.opennetworking.org](http://www.opennetworking.org)
The Traditional Network...

Control and Data Plane resides within Physical Device
Control plane learns/computes forwarding decisions
Data plane acts on the forwarding decisions

Control Plane (CP)
Data Plane (DP)
The Network As It Could Be…to an SDN ‘Purist’

Control plane becomes centralized
Physical device retains Data plane functions only
Evolution to SDN

Current switch/router

“SDN” Approach

Emerging: Hybrid Model

- Resilient, Scalable
- Simpler (fewer nodes to manage)
- Best of both worlds

Vendor-specific APIs

Control Plane

Data Plane

Control Plane

OpenFlow or Vendor-specific

Control Plane

Standards-based APIs??

Control Plane

Data Plane

Data Plane
The Network As It Could Be… In a ‘Hybrid SDN’

A Controller is centralized and separated from the Physical Device, but devices still retain a localized Control plane intelligence.
Software Defined Networking and Software Defined Storage do they work together?
SDN & SDS

- Two ways of abstracting underlying hardware from a management/control plane perspective for their respective supported technologies

- SDN and SDS do not have anything to do with each other
  - SDN controllers do allow storage application to interact with one control plane (the controller) versus every networking device they are running on.
What is an SDS Controller

**Data Services**
- Application that runs in data plane to optimize storage
- Ex: Predictive Analytics
- Ex: De-Duplication
- Ex: Tiering

**SDS Controller**
- Visibility and Control of ALL storage resources
- Communication between Apps, Orchestrator and Storage Systems
- Allocates storage resources to meet SLA’s
Where do SDS and SDN interact?

The diagram illustrates the interaction between SDS (Storage Device Services) and SDN (Software Defined Networking). SDS controllers are connected through Northbound APIs to an Orchestrator. SDN controllers are also connected through Northbound APIs to the Orchestrator. SDS controllers manage storage systems with their own capacity and performance, while SDN controllers manage the network infrastructure.
Key Takeaways

- SDN and SDS controllers are not the same thing
  - SDN controllers primarily control the management and flow creation of networking devices
  - SDS controllers primarily control the visibility and provisioning of all storage resources
- Both use northbound API to tie into applications and orchestration.
Summary

- Controller is a confusing historical term.
- Context is important – is it the whole array (controller + storage) or is it just the controller or is it the adapter card stuck into a PCI slot
  - Storage Array (usually the whole thing)
  - Array Controller (usually the controller in the array)
  - Storage Controller (usually the controller in the array – or a simple PCI adapter card)
  - Logic Controller (as used in Software-Defined Storage systems)
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- 8 More “Everything You Wanted To Know About Storage But Were Too Proud To Ask” on-demand at:
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