Fibre Channel Interoperability

Live Webcast
Aug 23, 2018
10:00am PT // 1:00pm ET

About the FCIA

"The Fibre Channel Industry Association (FCIA) is a mutual benefit, non-profit, international organization of manufacturers, system integrators, developers, vendors, and industry professionals, and end users."

Today's Speakers

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BoD, FCIA

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Senior Engineer

University of New Hampshire IOL

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HPE

Agenda

- A brief history of interoperability
- Standards, Conformance, and Interoperability
- FCIA sponsored plugfest events
- Fibre Channel systems Interoperability (shall)
- Fibre Channel systems Compatibility (should and can)
- FC ports – the importance of NPV and NPIV
- Many dimensions of Interoperability
- Summary

Fibre Channel (FC)

Fibre Channel (FC) is a high-speed network technology that interconnects network elements and allows them to communicate with one another

- The International Committee for Information Technology Standards (INCITS) T11 Technical Committee sets FC standards
- FC networks provide high-performance characteristics such as lossless transport combined with flexible network topology
- FC is primarily used in storage area networks (SANs) because it provides reliable, lossless, in-order frame transport between initiators and targets.
- FC components include initiators, targets, and FC-capable switches that interconnect FC devices and may also interconnect FC devices with Fibre Channel over Ethernet (FCoE) devices. Initiators originate I/O commands. Targets receive I/O commands.
  - For example, a server can initiate an I/O request to a storage device target

University of New Hampshire InterOperability Lab (UNH-IOL)

- The UNH-IOL is a non-profit neutral, third-party laboratory dedicated to testing data networking technologies through industry collaboration. It was founded on the concept of Interoperability

- Since early 2000's, FCIA has collaborated with UNH-IOL to hold plugfest and test events to verify the conformance and interoperability of Fibre Channel products.
  - ✓ UNH-IOL has conducted more than 39 plugfests with FCIA over 18 years, to test the continued development of FC technologies

- The UNH-IOL has over 80 Interop test offerings

A Little History

- **Interoperability: the ability of computer systems of software to exchange and make use of information; ability of a system to work with or use the parts or equipment of another system**
- The FC Industry has been evolving over the last 20+ years through increase in speeds, number of feeds, and new protocols in storage networks
- The creation of any new aspect of a storage network requires unit, system, conformance, performance and interoperability testing
- There is an order

Conformance THEN Interoperability

- It all starts with conformance testing
- FC has layers: FC-0 up to FC-4
- Once a device adheres to conformance standards then Interoperability testing can happen between devices
- Next, there are system tests that include a larger number of unique products performing Interoperability on many different storage features

Fibre Channel Standards

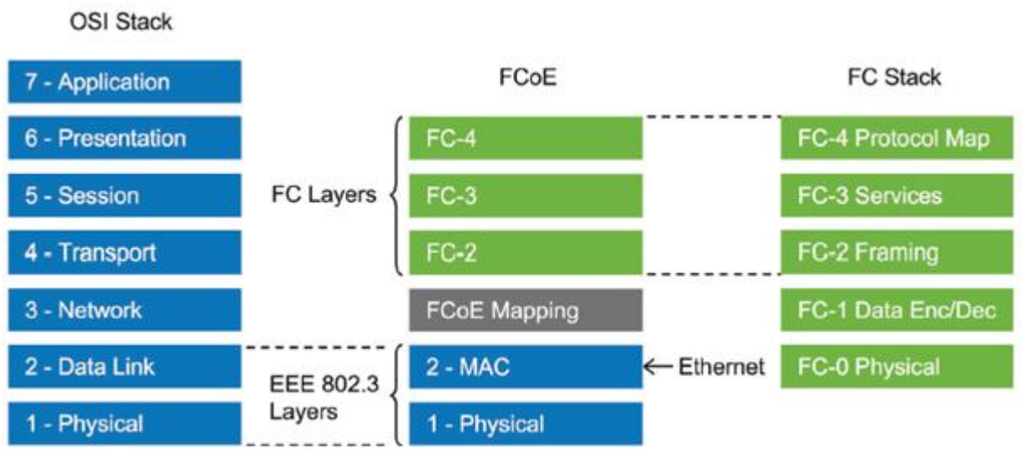
FC-NVME	**Fibre Channel – Non-Volatile Memory Express**
FC-NVME-2*	**Fibre Channel - Non-Volatile Memory Express 2**
FC-FS-4	**Fibre Channel - Framing and Signaling - 4**
FC-FS-5	**Fibre Channel - Framing and Signaling - 5**
FC-FS-6*	**Fibre Channel - Framing and Signaling - 6**
FC-PI-6	**Fibre Channel - Physical Interfaces - 6**
FC-PI-6P	**Fibre Channel - Physical Interfaces - 6 Parallel**
FC-PI-7	**Fibre Channel - Physical Interfaces - 7**
FC-PI-7P*	**Fibre Channel - Physical Interfaces - 7P**
FC-PI-8*	**Fibre Channel - Physical Interfaces - 8**
FC-EE	**Fibre Channel - Energy Efficiency**
FC-GS-7	**Fibre Channel - Generic Services - 7**
FC-GS-8*	**Fibre Channel - Generic Services - 8**
FC-SW-6	**Fibre Channel - Switch Fabric - 6**
FC-SW-7*	**Fibre Channel - Switch Fabric - 7**
FC-BB-6	**Fibre Channel - Backbone - 6**
FC-LS-3	**Fibre Channel - Link Services - 3**
FC-LS-4*	**Fibre Channel - Link Services - 4**
FC-SB-6	**Single-Byte Command Code Sets - 6**
FC-SB-7	**Single-Byte Command Code Sets - 7**
FC-SP	**Fibre Channel Security Protocols**
FC-SP-2	**Fibre Channel Security Protocols - 2**
SM-HBA-2	**Host Bus Adapter Application Programming Interface 2nd Generation**

* Standard in T11 Development

Fibre Channel Layers

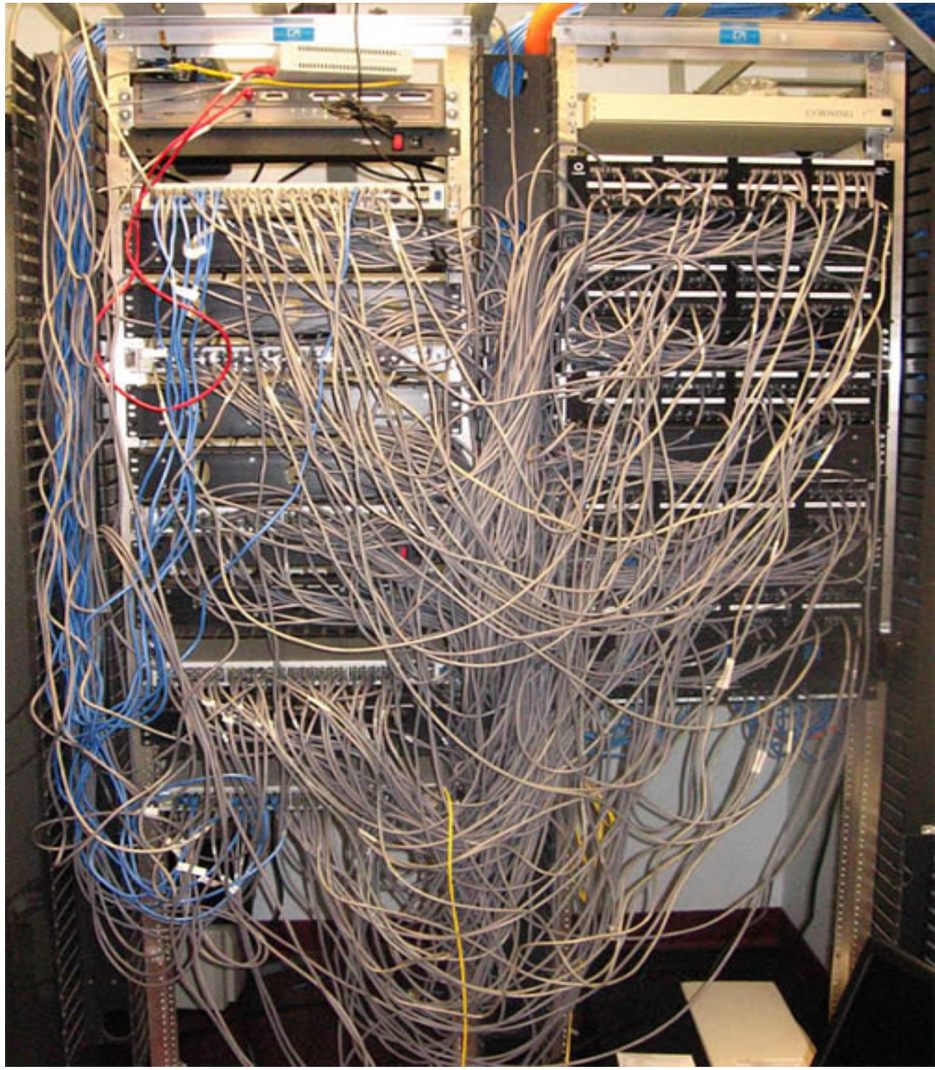
FC has functional layers:

- **FC-0**: The interface to the physical media; transceivers, cables, etc.
- **FC-1**: Transmission protocol or data-link layer, encodes and decodes signals
- **FC-2**: Network Layer consists of the low level Fibre Channel protocols; port to port connections.
- **FC-3**: Common services layer, a thin layer that could eventually implement functions like encryption or RAID redundancy algorithms; multiport connections
- **FC-4**: Protocol-mapping layer, in which upper level protocols such as NVMe, SCSI, IP or FICON, are encapsulated into Information Units (IUs) for delivery to FC-2.



FC-0 Testing

- Physical layer testing including connectors, transceivers, and cabling types
- Optical and electrical parameters
- Electrical
  - Short distances
- Optical
  - Longer distances (Single-mode)
  - Shorter distances (multi-mode)



FC-0 Interoperability

- Point to point interop insures signal integrity, compatible physical variants & data rates
- Acceptable jitter
- Verification of BER that is within acceptable levels
- Acceptable signal state change & amplitude levels

FC-1 Testing

- Transmission & Reception decode testing 64b/66b &8b/10b)
- Transmission signaling and control
  - Start of frame (SoF)
  - End of frame (EoF)
- Low level link protocols

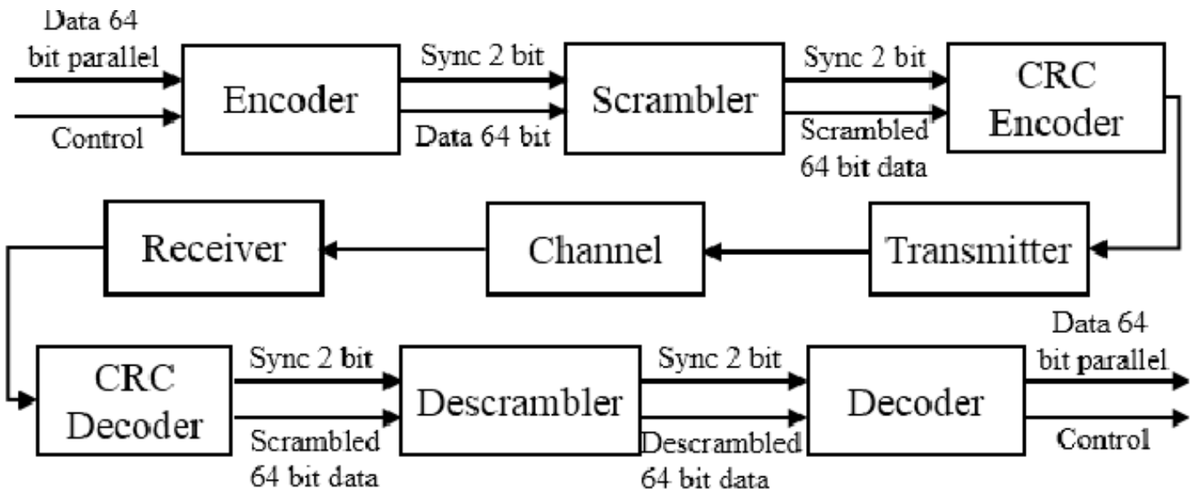


Figure 1. Implemented system architecture with 64b/66b encoding scheme

FC-1 Interoperability

- Transmission & Reception decoding works correctly
- Ordered sets
- Link Level protocols using order sets

FC-2 Testing

- Login Sessions
- Exchange management, IUs
- Frame formats, CoS
- Link control

FC-2 Interoperability

- We now have signals that sync correctly, we have control of port link state machines, we have primitive signaling. All a good start!

- Next is interoperability of extended link services, data exchanges, and Information unit (IU) exchanges

FC-3&4 Testing

- Generic Service interoperability
- Higher layer protocols that use Fibre Channel as a transport
- This is where interoperability it essential, seen with the advent of newer storage technologies such as Flash and NVMe
- Interoperability of NVMe storage data over Fibre channel FC-NVMe) requires Initiator, target and switch to work seamlessly

FC-3&4 Interoperability

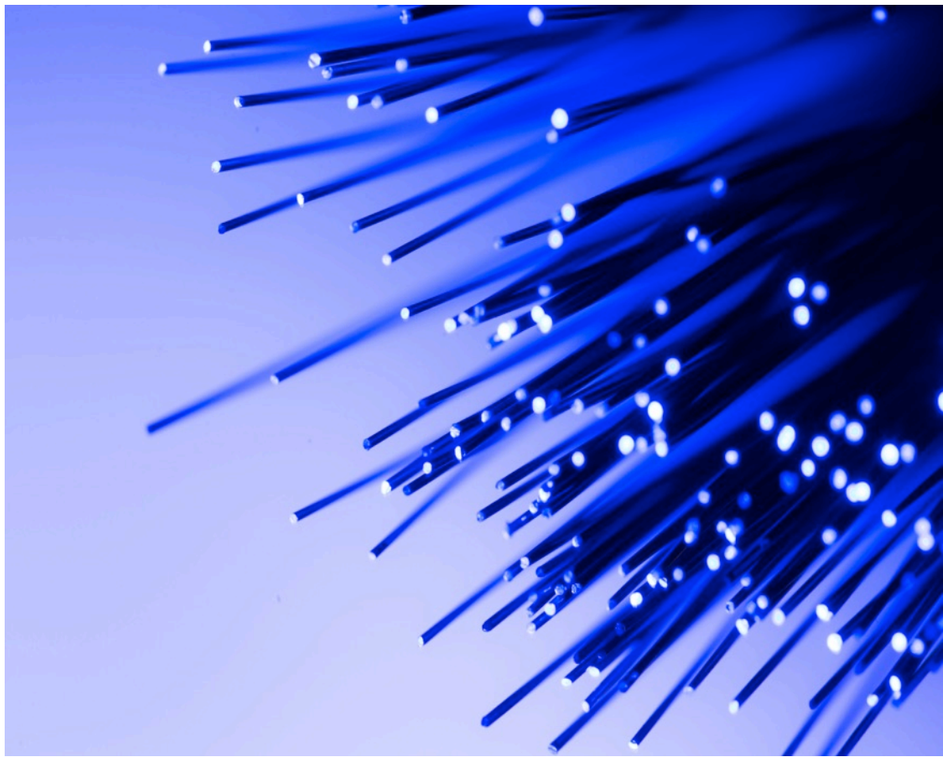
- Point to Point is great, but a storage Fabric (SAN) is the best
- FC switches in a Fibre Channel fabric
- Upper Level Protocols bring a new level of interoperability testing

Conformance WITHOUT Interoperability

- Doesn't work, the IOL is the perfect example of this fact
- Conformance Standards can be vague in many instances
- Conformance Standards can be interpreted differently by different implementors
- But Conformance Standards do a very good job of allowing for the products to be created similar enough to allow for those products to co-exist in the same environment
- The latest example of conformance and Interoperability is FC-NVMe

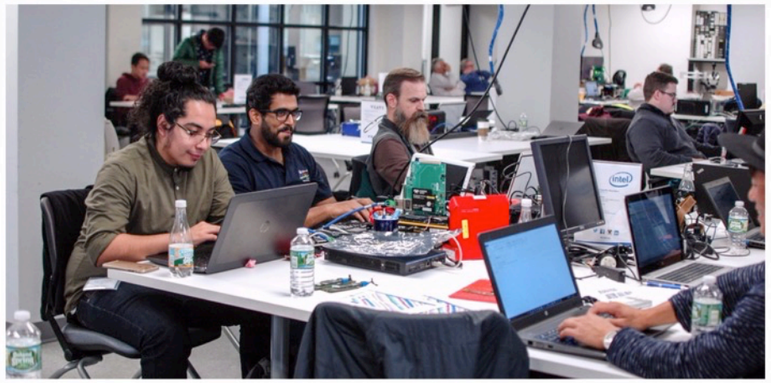
System Interoperability Testing

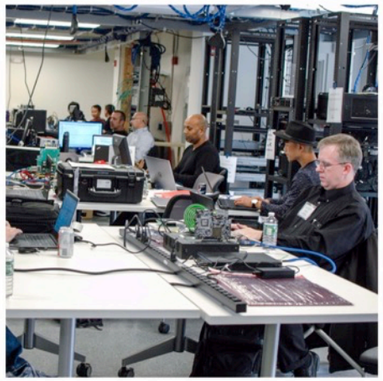
- Conformance to standards allows for basic interaction between network devices at each FC layer
- Interoperability testing allows for network devices to verify all conforming functionality
- System Network testing provides the combination of conformance and interoperability testing to verify large scale deployment of unique vendor products



Plugfest Testing is a great Interoperability workout

- FC plugfests are typically held once or twice a calendar year and allow companies in the FC Industry a chance to come together to make sure their newly developed features and functions conform to standards and interoperate
- The latest plugfests deal with newer speeds and the latest upper level (FC4) protocol NVMe
- Other areas such as error injection and recovery have been recent interoperability tests that have proven integral for the industry
- More on interoperability, standards, and test events…..





Fourth 32GFC&FC-NVMe Focused Plugfest
13 participating companies

FCIA
Members CARE about Interoperability!

- Amphenol Corporation
- Broadcom, Inc. Brocade
- Broadcom, Inc. Emulex
- Cisco Systems, Inc. MDS
- Cisco Systems, Inc. UCS
- Data Center Systems (DCS)
- Dell EMC
- Hewlett Packard Enterprise (HPE)
- Marvell Technology Group Ltd., Cavium QLogic
- NetApp Inc.
- SANBlaze Technology, Inc.
- Teledyne LeCroy, Inc.
- Viavi Solutions Inc.

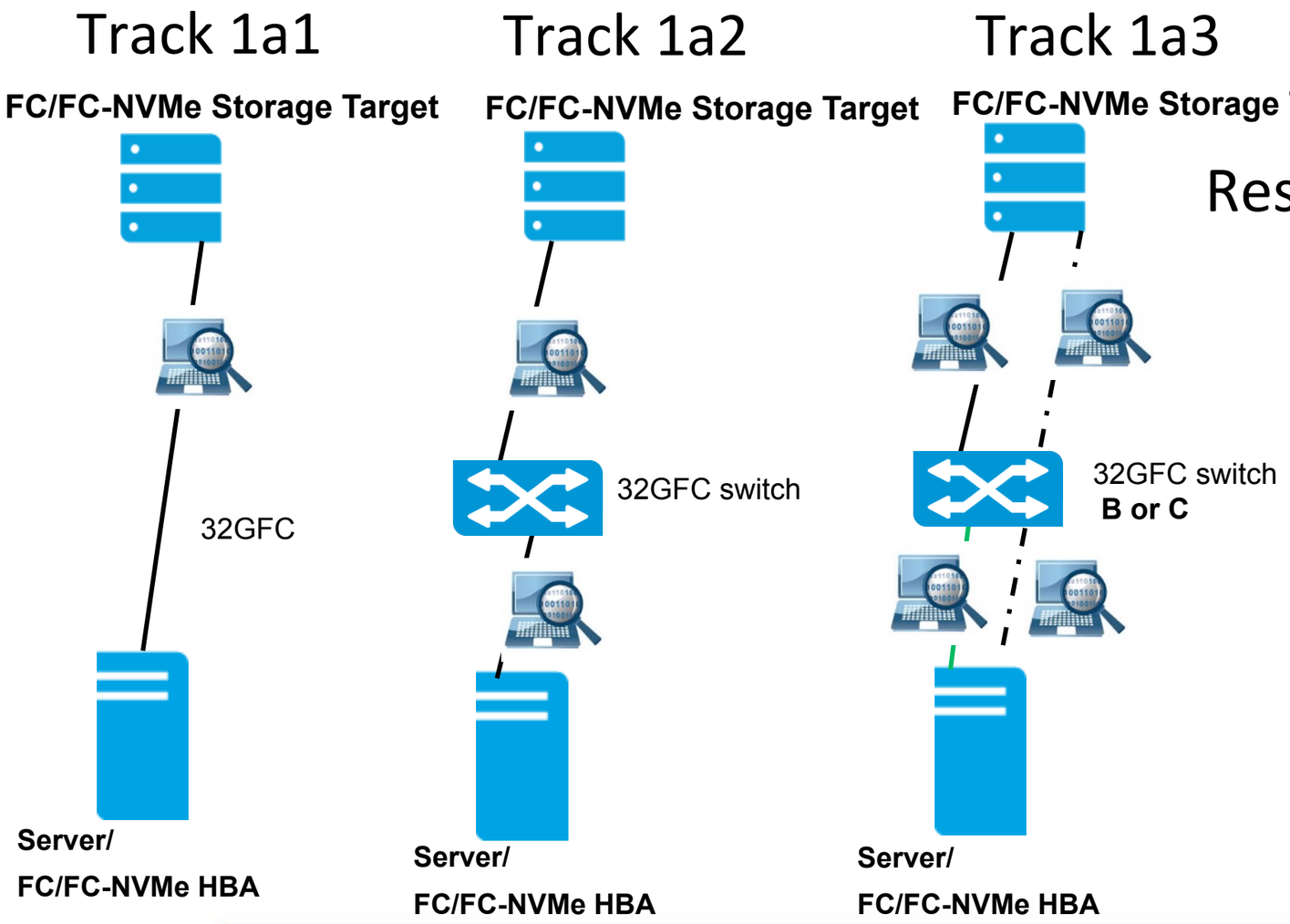
32GFC & FC-NVMe Maturity Demonstrated

FCIA completed its fourth multi-vendor interoperability plugfest focused on the 32GFC and FC-NVMe the week of July 23, 2018 at Austin Labs

Key accomplishments from this fourth FCIA-sponsored plugfest of FC-NVMe include:

- Testing of commercially available enterprise market storage arrays with FC-NVMe
- Multiple vendor initiator, switch, and target FC and FC-NVMe conformance and interoperability
- 32GFC fabric connectivity to a variety of market available NVMe drives
- Data integrity validation over multi-vendor direct-connect and switched multi-hop fabric topologies
- Error injection tests to validate correct FC-NVMe and FC recovery and data integrity
- Concurrent FC-NVMe and FC through the same initiator, fabric, and target ports
- Blade servers' utilization of NVMe over FCoE
- Successful demonstration of 32GFC active optical cables (FC-AOCs)

PlugFest is focused, by Test Tracks, on layers of FC functionality starting with link\login\data integrity

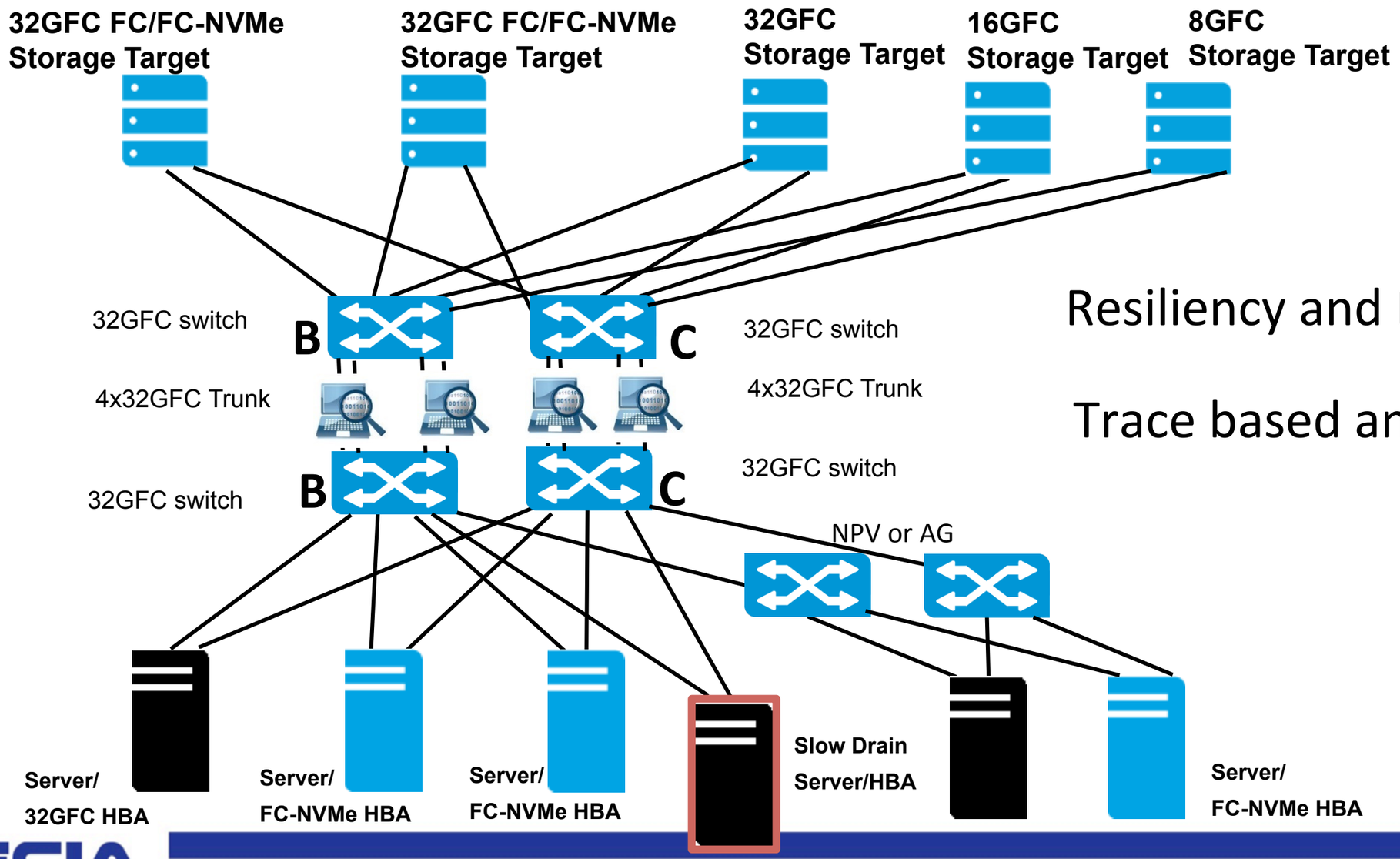


Resiliency and Data Integrity

Add 2nd Initiator port and then 2nd target port

Trace based analysis

Plugfest Interoperability test success based on high availability multi-hop fabric stability

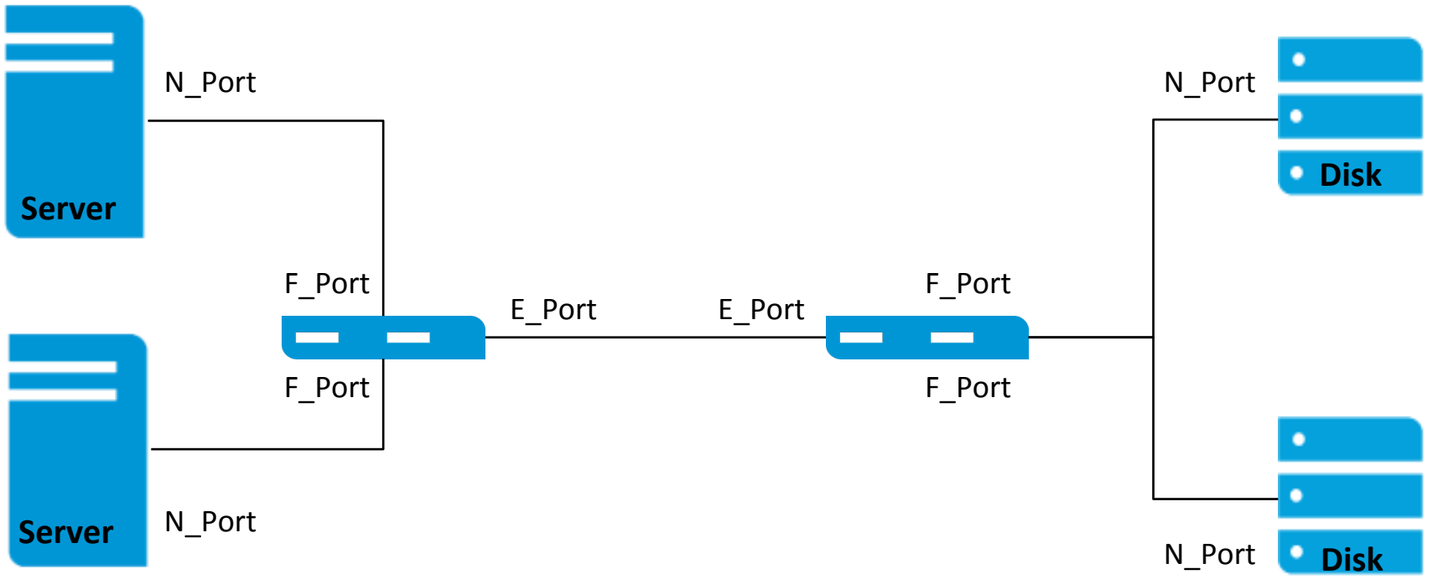


Resiliency and Data Integrity

Trace based analysis

FC Port Types

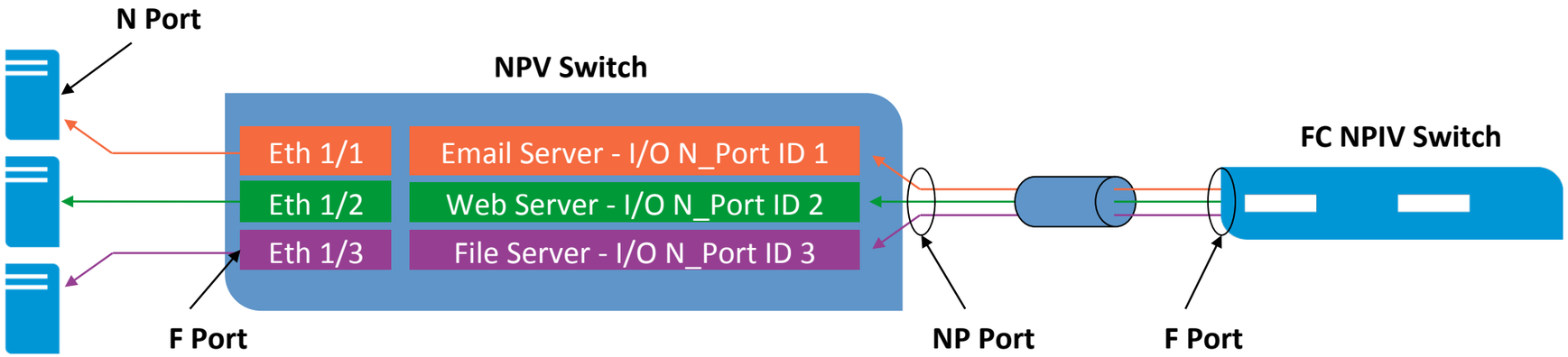
- Node ports (Server or Storage)
  - N_Port: directly connect to Fabric
- FC Switch ports
  - F_Port: Fabric ports, to N_Port
  - E_Port: Extended ports (Switch to Switch)
  - NP_Port: N_Port Proxy port



NPV and Access Gateway (AG)

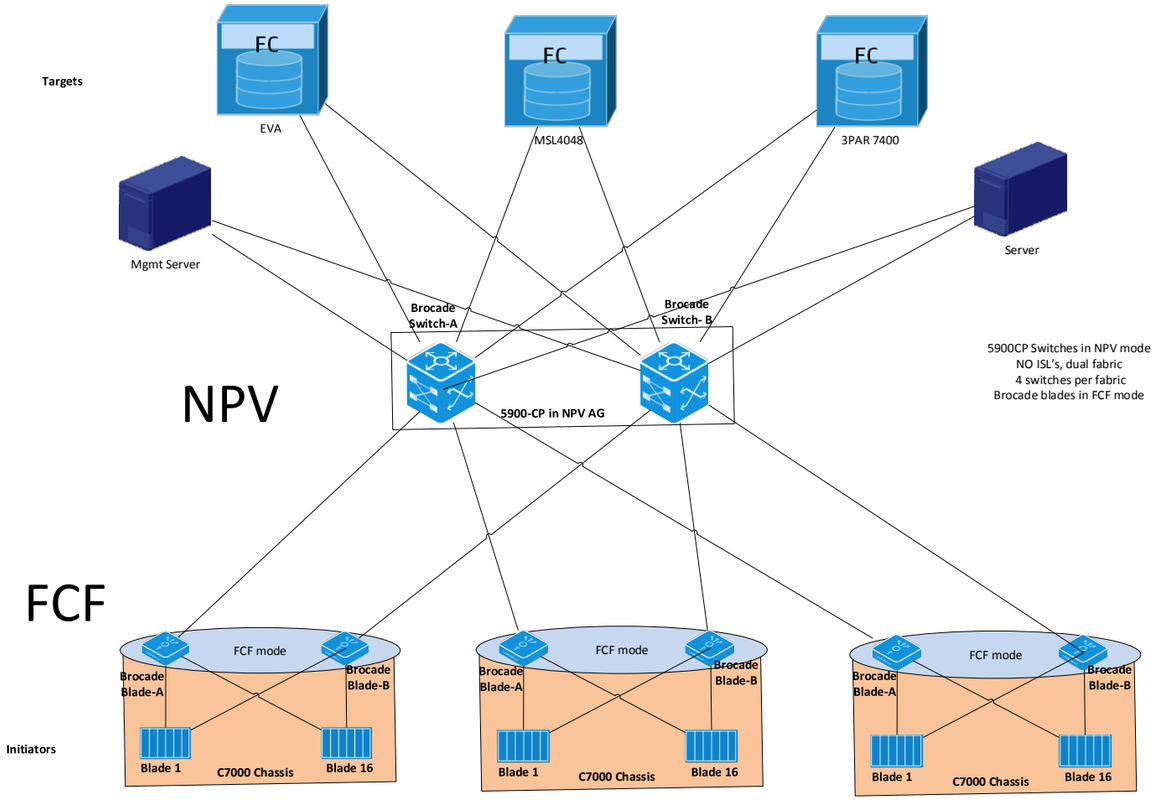
- N-Port ID Virtualization (NPIV)
  - NPIV allows a Fibre Channel host connection or N-Port to be assigned multiple N-Port IDs or Fibre Channel IDs (FCID) over a single link
    - All FCIDs assigned can now be managed on a Fibre Channel fabric as unique entities on the same physical host
    - In a virtual machine environment where many host operating systems or applications are running on a physical host, each virtual machine can be managed independently from zoning, aliasing, and security perspectives

- N-Port Virtualizer (NPV or AG)
  - The N-Port Virtualizer allows the blade switch or top-of-rack fabric switch to behave as an NPIV-based host bus adapter (HBA) to the Fibre Channel fabric controller
  - The device aggregates and serves as a proxy for the locally connected host ports or N-Ports into one or more uplinks (pseudo-inter switch links) to the fabric switches

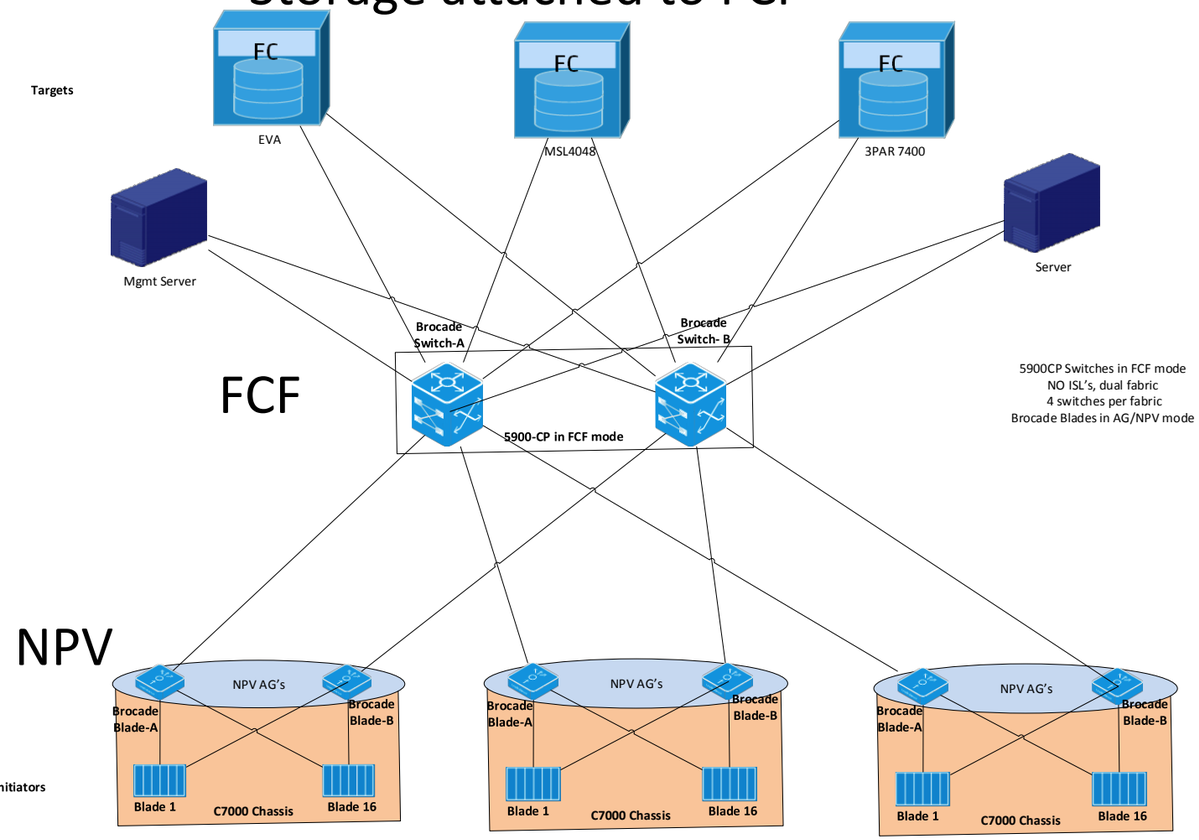


Example: misused NPV mode; multi-vendor SAN

Not recommended
- Storage attached to NPV switch



Recommended
- Storage attached to FCF



Interoperability

Motivation for FC Interoperability – TRUSTed through validation

Compliance: the action or fact of complying with a wish or command; conformity; accordance

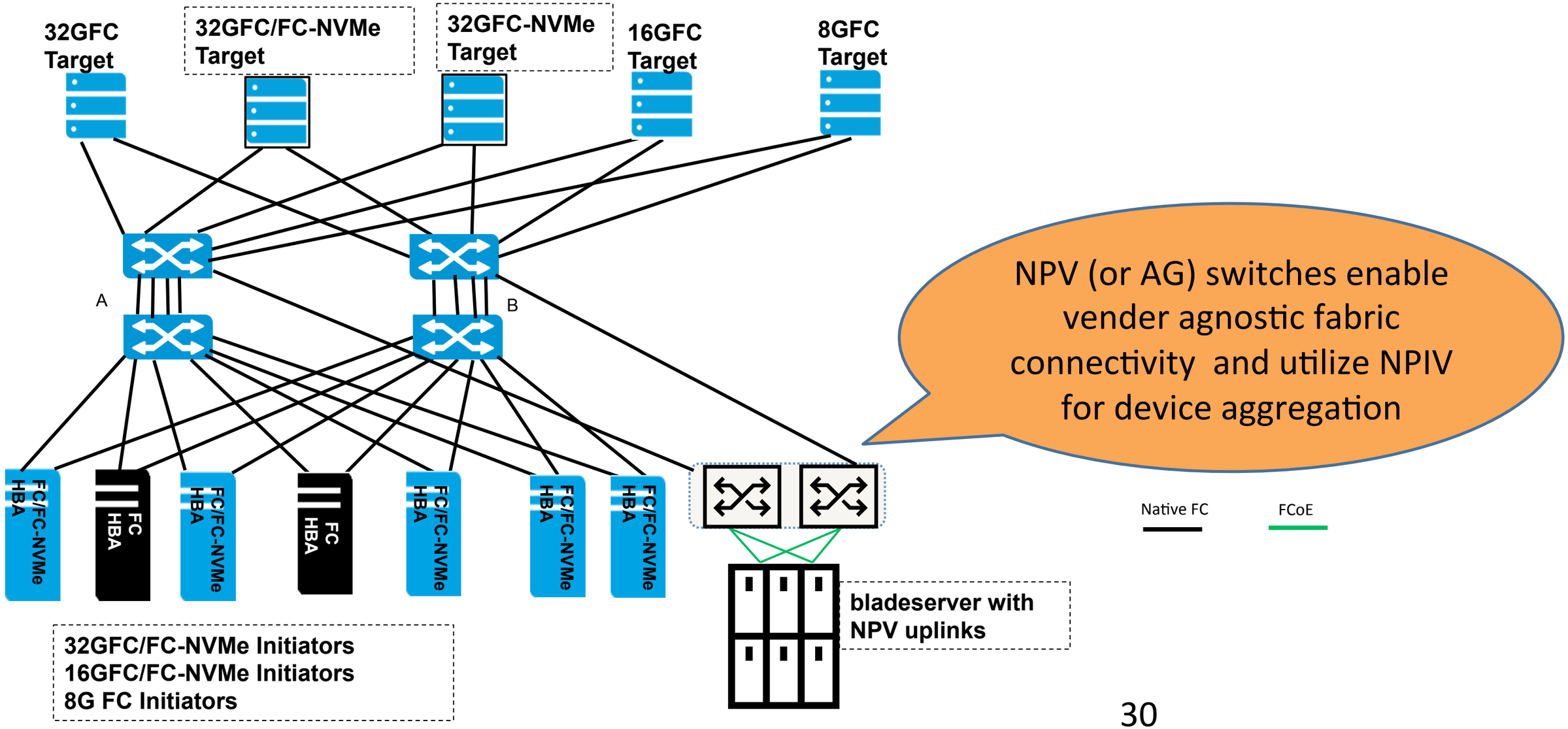
Conformance: another term for conformity; to be in conformance with all the standards

Compatibility: a state in which two things are able to exist or occur together without problems or conflict; the ability of one computer, piece of software, etc., to work with another

Data Integrity: FC standards and FC protocol have unique deterministic and reliable block storage transport characteristics to protect what is important:

your data and data availability

Fibre Channel Interoperability Validation



Interoperability and Compatibility Matrices

- PROVEN INTEROPERABILITY
  - E-Lab has tested and qualified millions of different data center configurations, giving you the confidence you need to deploy leading-edge technologies; E-Lab tests and qualifies EMC Proven Solutions
- Brocade Fabric OS 8.x Compatibility Matrix
- Cisco Storage Interoperability Matrix
- Cisco Fabric Services Interoperability Matrix
- CISCO Switch Interoperability Matrix
- ATTO Celerity Fibre Channel HBA Interoperability Matrix
- VMware Compatibility Guide
- VMware Management & Orchestration
- Hardware Universe (HWU) application as the authoritative source for platform mixing requirements.
- HPE Single Point of Connectivity Knowledge (SPOCK) website.
  - SPOCK is the primary portal used to obtain detailed information about supported HPE Storage product configurations

Multivendor Interoperability testing is the backbone of FC solutions

Standards as Interoperability Building Blocks

- Fibre Channel standards provide criteria and definition for interoperability test development based on conformance
  - **shall** - denotes a requirement that is mandatory whenever the criterion for conformance with the specification requires that there be no deviation
- T11 Standards
  - FC was and still is defined by the FC industry members
  - Organizations trust Fibre Channel technology because of purpose built technology which is interoperable
  - Establish criteria for implementation validation while also serving to define interoperability requirements
  - Provide a means to determine what can be done and how a standards-based solution can be implemented
  - Allow for definition of testing criteria to measure against
- Generally, standards-compliance provides the criteria for interoperability because there are quantifiable tests that the standards provide

Standards as Interoperability Building Blocks

- Fibre Channel standards provide criteria and definition for interoperability test development based on conformance
  - **should** - denotes a guideline, best practice, or recommendation whenever noncompliance with the specification is permissible
    - (implementation choices permitted)
  - sometimes use of **can** and **will** are accepted – these statements imply intent and require verification
  - standards avoid **must, might, could,** and **may** – these statements are not subject to verification

Standards as Interoperability Building Blocks

- Example: a third party testing group learns the T11 FC standards, understands how something **shall**, **should,** and can function, and then independently measures whether or not an implementation claim of compliance and interoperability is truthful (or not)
  - Negative testing is in scope of conformance to **SHALL** conditions

- FC solutions are constantly validated by FC technology developers, as well as 3rd party integrators, testing, and solution providers
  - Vmmark - a free tool used to measure the performance and scalability of virtualization platforms
  - Demartek focuses on real-world, hands-on industry analysis and lab validation
  - Tolly Group Third-Party validation is the time-tested best way to put the power of proof behind claims
  - Teledyne LeCroy's Austin Labs is the premier third-party test and validation center for data center devices

- Tools have been developed to facilitate protocol conformance and interoperability
  - Viavi Xgig protocol analyzers, Xgig Expert Software, and Medusa Labs Test Tool
  - Teledyne LeCroy SierraNet protocol analyzers and Analysis Software (CATC Trace viewer)
  - Spirent TestCenter's 7-Speed 16/32G (FC) / 10/25/40/50/100GE module - complete FC to FCoE testing in a single system

Conformance and Interoperability Testing Programs

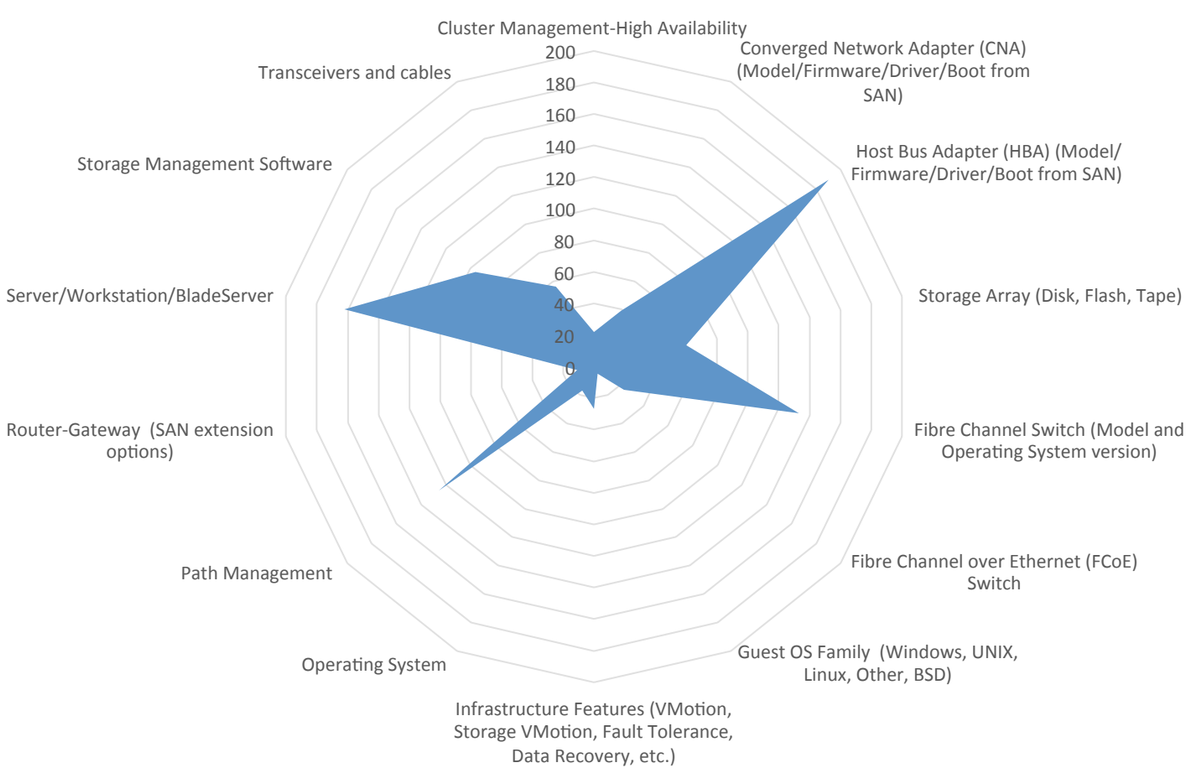
- 3rd party conformance testing is vendor independent, industry vetted, and cost-effective, benefiting both vendors and end users
- Vendor and Manufacturer benefits: (It costs a lot to be **TRUSTed!**)
  1. Reduced integration costs
  2. Satisfy customer demand for standards-based solutions
- End User and Customer benefits:
  1. Objective testing, results verified in a vendor-neutral manner
  2. Ensured equipment conformance to FC standards
  3. Lower cost of ownership through proven generational interoperability
  4. Helps to prevent vendor lock-in to unique features and implementations
  5. Improved interoperability of multi-vendor products

Many Dimensions of FC Interoperability

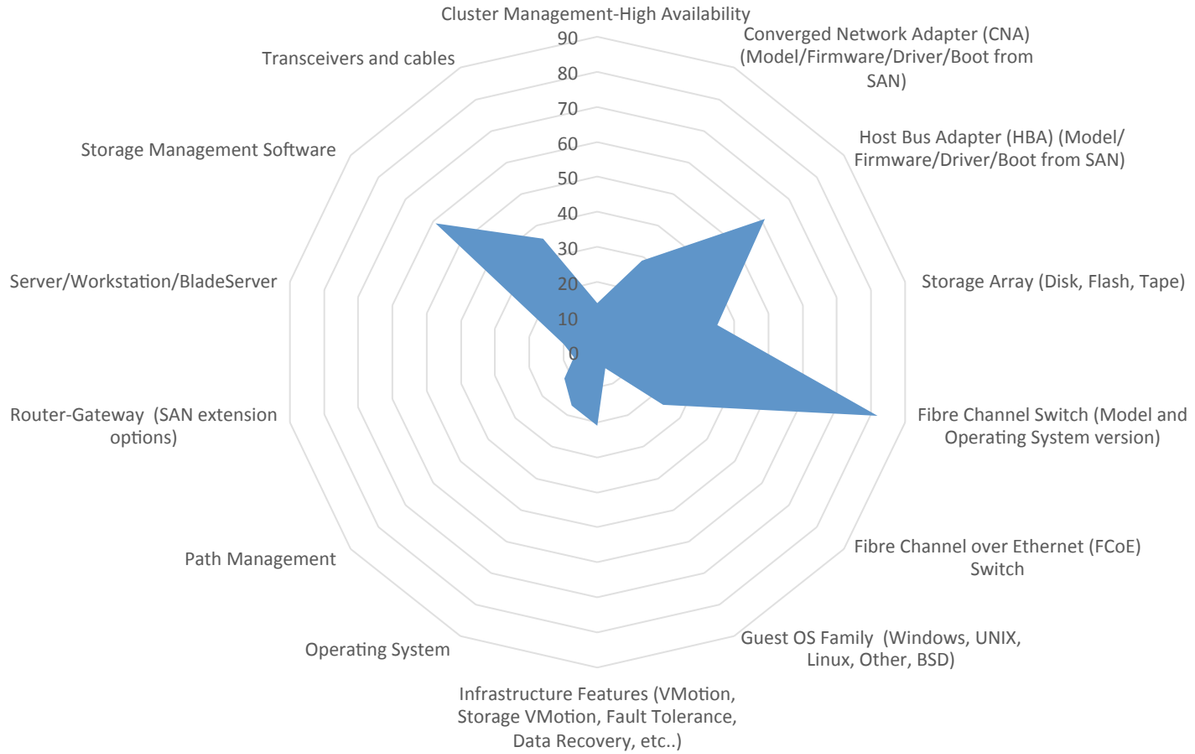
- Generational interoperability and compatibility is a requirement
- Interoperable FC devices have to work with multi-vendor devices at multiple link rates and with varied optional features
- Interoperability enables migration to another vendor for some components of the SAN
  - primarily end devices
- SAN scale is an issue of conformance, interoperability, and compatibility
- The FC stack doesn't change significantly as link speeds increase
  - the FC protocol doesn't change when the link speed increases
- Interoperability is documented by fibre channel equipment vendors
  - revision matrices including OS versions, adapter versions, adapter firmware versions, transceivers and cables, switches and switch OS versions, storage and storage software versions, management interfaces – CLI, GUI, public and private (MIBs), SMI-S, SNMP, CIM provider, RESTful APIs, custom applications

Interoperability Dimensions

Interoperability cases viewed by 8GFC HBA



Interoperability cases viewed by 32GFC HBA



Interoperability Dimensions by 8GFC HBA

View Interoperability By PCIe 8GFC HBA	View by options
Cluster Management-High Availability	22
Converged Network Adapter (CNA) (Model/Firmware/Driver/Boot from SAN)	39
Host Bus Adapter (HBA) (Model/Firmware/Driver/Boot from SAN)	190
Storage Array (Disk, Flash, Tape)	60
Fibre Channel Switch (Model and Operating System version)	133
Fibre Channel over Ethernet (FCoE) Switch	24
Guest OS Family (Windows, UNIX, Linux, Other, BSD)	5
Infrastructure Features (VMotion, Storage VMotion, Fault Tolerance, Data Recovery, etc.)	27
Operating System	17
Path Management	126
Router-Gateway (SAN extension options)	11
Server/Workstation/BladeServer	162
Storage Management Software	96
Transceivers and cables	56

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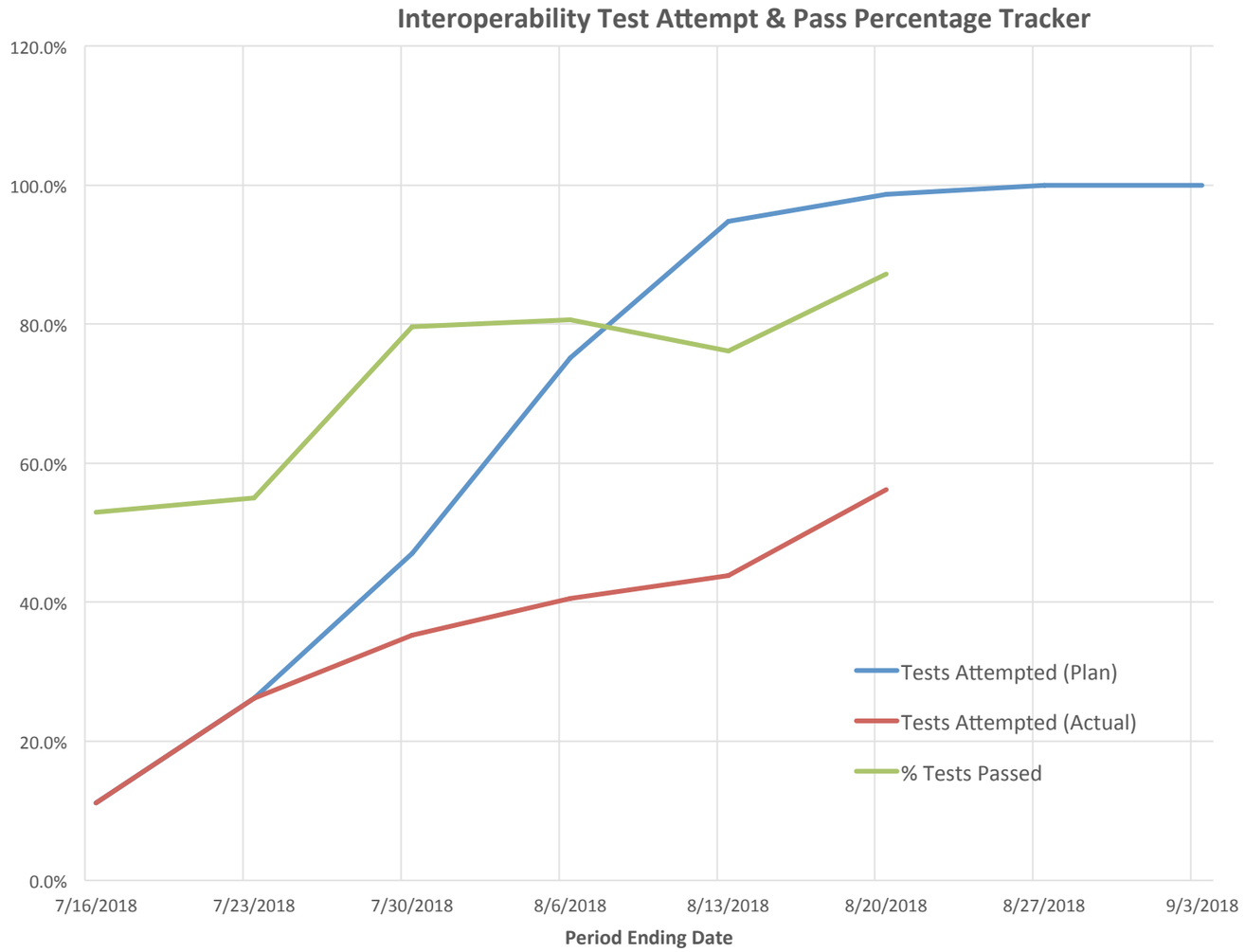
Operating System	17
Path Management	12
Router-Gateway (SAN extension options)	7
Server/Workstation/BladeServer	10
Storage Management Software	59
Transceivers and cables	36

Example: Interoperability Test Tracking



Example: View of Storage Array by Interoperable OS

	AIX	CentOS	Citrix XenServer	HP-UX	Oracle Linux	Oracle VM	Red Hat	Red Hat Virtualization	Solaris	SUSE	Ubuntu	VMware	Windows 2016	Windows 2012	Windows 2008
Storage H-Series FC	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Storage S-Series FC	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Storage F-Series FC	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔

Multi-generational Compatibility

Examples of functions which impact compatibility – and are normally configurable or negotiated by protocol

- Transceivers, DAC cables, AOCs, fiber
- Auto speed negotiation
- FEC (32GFC mandatory and 16GFC optional)
- FCP features
- BB credit recovery
- BB credit tuning for distance applications
- Zoning and Alias names, enhanced zoning, and target driven zoning
- Hard and soft zoning
- Slow drain device detection and management
- Device and Fabric priority
- Fast write schemes
- D-port Diagnostics
- T10 Diff and Dix
- Port Security
- FDMI-2 name service database registration
- Operating system neutral – all major operating systems run on common FC infrastructure
- SNMP (public and private MIBs)
- SMI-S
- FC-NVMe fabric registration, capability identification, and telemetry monitoring

FC providers shall be held to standards

If you need to migrate from 8GFC to 16GFC or 32GFC to improve throughput and reduce latency, that doesn't mean everything must change

Link rate is often the top item used when comparing FC generations, however - the feature set is the same from one rate to another

- when the physical layer of Fibre Channel changes, the upper layers of the protocol don't need to change unless you want to utilize new features or functions which come with FC evolution

- As we pointed out - Fibre Channel uses a layering system, the link rate can increase without affecting other features of Fibre Channel

Link speed compatibility

Product Naming	Throughput (Mbytes/s)	Line Rate (Gbaud)	T11 Specification Technically Complete (Year)	Market Availability (Year)
8GFC	1,600	8.5	2006	2008
16GFC	3,200	14.025	2009	2011
32GFC	6,400	28.05	2013	2016
128GFC	25,600	4X28.05	2014	2016
64GFC	12,800	28.9 PAM-4 (57.8Gb/s)	2018	2019
256GFC	51,200	4X28.9 PAM-4 (4X57.8Gb/s)	2018	2019

FC-PI-7 proposed standard in comment resolution

Product Naming	Throughput (MBytes/s)	Line Rate (Gbaud)	IEEE Standard Complete (Year)*	Market Availability (Year)
10GFCoE	2,400	10.52	2002	2008
25GFCoE	6,000	25.78125	2016	Market Demand
40GFCoE	9,600	41.25	2010	2013
50GFCoE	12,000	26.5625 PAM-4 (53.125 Gb/s)	2018	Market Demand
100GFCoE	24,000	4X25.78125	2015	Market Demand

Link speeds are backward compatible with at least two previous generations
(I.e., 32GFC compatible to 16GFC and 8GFC and 100GbE compatible to 25GbE and 10GBE)

FC Interoperability Then, Now, and Tomorrow

layered standards
multi-generation interoperability
multi-generation compatibility
in-order lossless fabric transport
flexible (flash and FC-NVMe)
scalable

resilient high availability
innovative platform
trusted and rock-solid reliability
built in data integrity and security
predictable performance
long distance solutions
disaster proof solutions
interoperable speeds – future proof

After this Webcast

- Please rate this event – we value your feedback
- We will post a Q&A blog at http://fibrechannel.org/ with answers to all the questions we received today
- Follow us on Twitter @FCIAnews for updates on future FCIA webcasts
- Visit our FCIA webcast library at http://fibrechannel.org/webcasts/ to learn about:
  - Fibre Channel Fundamentals
  - FC-NVMe
  - Long Distance Fibre Channel
  - Fibre Channel Speedmap
  - FCIP (Extension): Data Protection and Business Continuity
  - Fibre Channel Performance
  - Fibre Channel Cabling
  - FICON

Our Next FCIA Webcast:

Protocol Analysis for High-Speed Fibre Channel Fabrics

October 10, 2018

10:00 am PT

Register at:

https://www.brighttalk.com/webcast/14967/333863

Thank You