Fibre Channel Solutions Guide 2019

25 YEAR ANNIVERSARY

FCIA

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FCIA

FIBRE CHANNEL INDUSTRY ASSOCIATION

FIBRE CHANNEL

Powering the next generation private, public, and hybrid cloud storage networks

ABOUT THE FCIA

The Fibre Channel Industry Association (FCIA) is a non-profit international organization whose sole purpose is to be the independent technology and marketing voice of the Fibre Channel industry.

We are committed to helping member organizations promote and position Fibre Channel, and to providing a focal point for Fibre Channel information, standards advocacy, and education.

CONTACT THE FCIA

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FOREWORD

By Rupin Mohan, FCIA Marketing Chairman; Director R&D and CTO, Hewlett-Packard Enterprise

It's 2019, and Fibre Channel continues to remain the premier storage fabric connectivity protocol in today's data centers. Fibre Channel is deployed by thousands of customers in their data centers around the world and 80–90% of all All-Flash storage arrays are connected to servers via Fibre Channel. Customers have recently made a considerable investment in Gen 6 (32GFC), and given the 4-5-year depreciation cycle, this equipment will continue to run critical business applications requiring reliable, fast and scalable storage infrastructure.

The NVMe over Fibre Channel (FC-NVMe) standard is published, and we see products being announced and released in the market across the board. Customers who have made investments in Fibre Channel will leverage the same hardware to run FC-NVMe. That just makes common sense. The INCITS T11 standards body is continuing to work diligently on the second version of FC-NVMe, which will greatly increase the reliability and stability of NVMe over Fabrics with FC-NVMe. We have an article on this specific topic in this year's Solutions Guide.

The fact that Fibre Channel was built from the ground up, and with an intense focus on enterprise storage array connectivity, gives FC-NVMe a unique edge over other network protocol standards in terms of rock-solid reliability, unmatched performance and massive scalability. The same solid foundation will get leveraged by NVMe over Fabrics for traditional applications that require the gold standard for performance - the "five nines of availability," meaning 99.999% of network uptime.

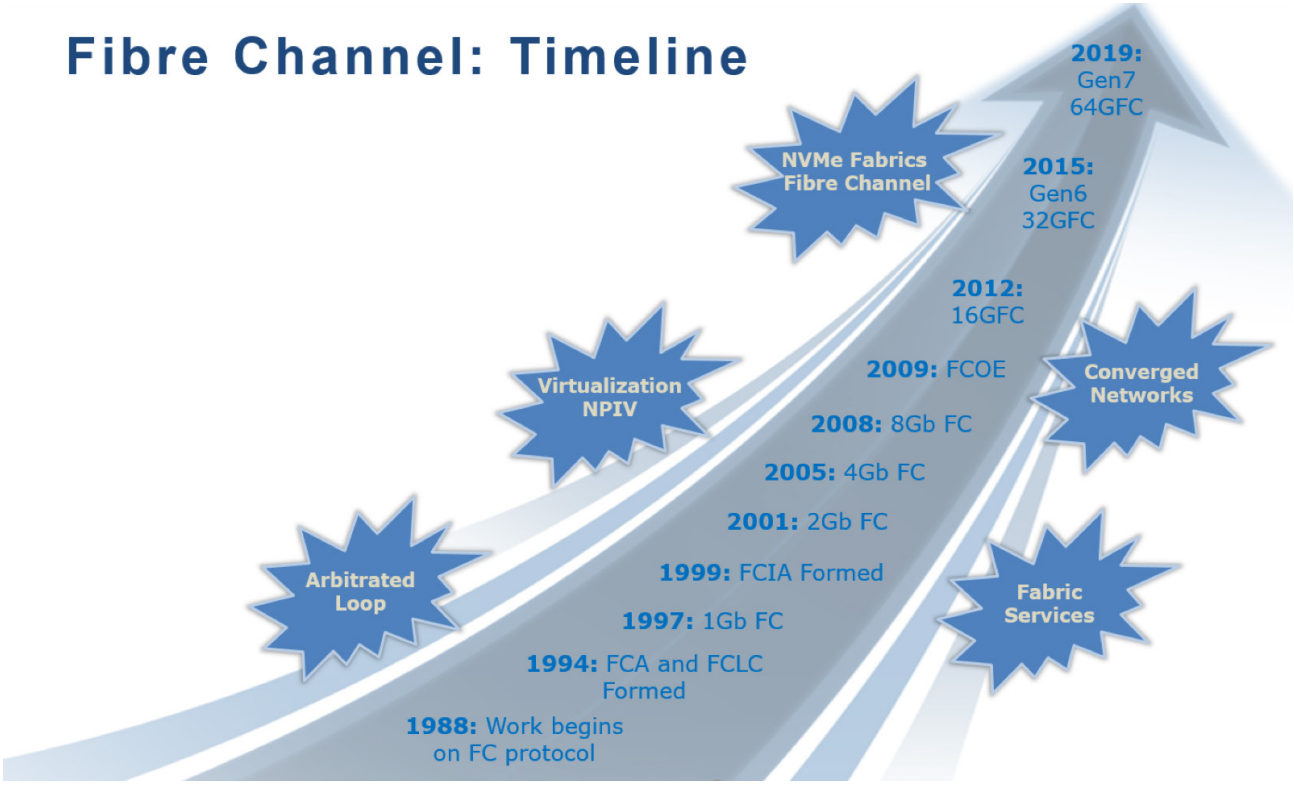
For the past few decades, several challengers have emerged, and folks have questioned if Fibre Channel's days are over, yet 2018 was a year of growth for Fibre Channel in terms of both ports and revenue. We have several good reads in the Guide this year on why this growth is happening and the details behind it. Also, the Fibre Channel roadmap continues to be robust. We have the next two generations of the technology mapped out and technologists are diligently working on delivering. To top it off, we have articles on the Media and Entertainment vertical market and a special focus on Security which continues to remain top of mind for CIO's.

Enjoy the Guide and learn more about the value that Fibre Channel can bring to your environment!

FCIA PRESIDENT INTRODUCTION

By Mark Jones, FCIA President; Director of Technical Marketing, Broadcom Inc., ECD

2019 marks the 25th anniversary of the Fibre Channel Industry Association (FCIA). In July of 1999, it was announced the non-profit organizations FCA (Fibre Channel Association) and FCLC (Fibre Channel Loop Community) would merge, forming what is now known as the FCIA. Both organizations date back five years before 1994, even before the SNIA (Storage Networking Industry Association) was formed, which was in 1998. In addition to the FCIA milestone, INCITS T11, the standards body that creates the Fibre Channel industry standards, recently celebrated its continuous 100th bi-monthly face-to-face meeting, signaling that the coalition for the Fibre Channel industry is still going strong!



The years have been good for the pioneering storage network technology, and in 2019 we've witnessed a resurgence in Fibre Channel adoption. Dell'Oro reports that Fibre Channel SAN revenue approached $2.5B in 2018, up 22% over 2017. Fibre Channel HBA and switch port shipments are also up 11% over 2017 to 7.7M representing an accumulation of over 127M ports shipped since 2001! In the last five years alone, 40M of those ports have been shipped, which illustrates just how large of a footprint Fibre Channel has in today's data centers. This is not what most of the industry press and analysts predicted, so why does Fibre Channel continue to be so popular?

Popular Fibre Channel Attributes	
Air Gap Redundancy	Best practice of physically separated SAN's, for example SAN A and B, gives customers the redundancy and no single point of failure
Backwards Compatibility	Each Generation of Fibre Channel is backward compatible two generations allowing for ease of migration to new technology generations
Cable Compatibility	Fibre Channel products have a history of cable and connector compatibility, which allows for seamless growth of structured cabling plants within the datacenter
High Performance	For 25 years, the FCIA roadmap has predictably managed a doubling of bandwidth every 3-5 years, keeping pace with data center technology refresh cycles
Datacenter Scale Manageability	Fabric services like zoning and name services offer industry unique levels of control and manageability
Link Efficiency	By design, Fibre Channel uses a buffer credit congestion management algorithm that allows for the highest fabric utilization without congestion slowdowns
Low Latency	Fibre Channel is inherently low latency

Another explanation for the recent resurgence in Fibre Channel growth is often attributed to the trend in the IT Industry of returning from deficient attempts to move towards the failed promises of overhyped new technology. A recent ESG article points to a study that revealed 41% of businesses surveyed last year brought at least one workload back from the cloud, citing security concerns as the number one reason.

The move towards all-flash arrays (AFA) continues to ramp up with double-digit growth expected through 2025. Nearly all of the major AFA vendors ship arrays with Fibre Channel ports included. This is necessitated by the extreme performance requirements of flash and NVMe storage, driving the growth of host HBAs and fabric switches. The completion of the T11 FC-NVMe specification in 2018 has resulted in nearly all Fibre Channel component suppliers providing NVMe over Fabrics solutions into the marketplace. In fact, of the major leading storage array vendors that have released NVMe over Fabrics connectivity, they have done so by leading with Fibre Channel FC-NVMe solutions.

In 2017, FCIA launched an Education Committee to amplify our outreach to Fibre Channel end users and developers by presenting live webcasts and blogging on important topics involving Fibre Channel technology. The topics range from entry-level education on current Fibre Channel usage to advanced topics and discussions on new advancements. We're very excited to already have over 3,700 subscribers to the channel as well as a strong number of visitors viewing the offline materials.

We encourage all those interested in learning more about Fibre Channel solutions to visit our BrightTALK channel.

The live FCIA presentations are hosted on the BrightTALK FCIA channel at www.brighttalk.com/channel/14967/the-fibre-channel-industry-association-fcia.

The FCIA webcasts are available for replay at your convenience, with presentation downloads and Q&A notes at fibrechannel.org/webcasts.

In addition to the FCIA BrightTALK channel, we encourage everyone to join in on the conversation by engaging with FCIA in our various social media channels:

Twitter: twitter.com/FCIAnews handle is @FCIANews

Facebook: www.facebook.com/FCIAnews

LinkedIn Company Page: www.linkedin.com/company/fibre-channel-industry-association

LinkedIn Group: www.linkedin.com/groups/138758

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[1] *Dell' Oro – Q418 Dell'Oro Worldwide SAN Report.*

[2] *ESG, 1/7/19, 2019 Data Storage Predictions: More Cloud Missteps, FC Is Back, and Finding Data Holds Back AI*

THE STATE OF FIBRE CHANNEL

By Storage Switzerland

Potentially, the only technology pronounced dead more often than Fibre Channel is tape, yet both are alive and well. In 2018, the Fibre Channel (FC) market saw a return to growth. According to Dell'Oro Group, FC SAN port shipments were up over 11 percent (7.7 million) compared to 2017. Total 2018 FC SAN revenue is expected to approach $2.5 billion, up nearly 22 percent over 2017. Not only is FC not dead, its growing and has the potential to surpass its glory years (2007-2014) where approximately nine million ports per year were sold.

What's Driving FC Resurgence?

Three data center trends are driving FC adoption. One of the biggest is the rapid growth of all-flash arrays thanks to NVMe & NVMe-oF. Today, most vendors supply all-flash arrays that are internally NVMe but connect to the network via standard SCSI (FC or iSCSI). Of the two choices, FC offers the latency that comes closest to matching the latency of NVMe. As these vendors move to adopt NVMe-oF, many are adopting NVMe-FC first and NVMe over FC adoption is expected to outpace the various NVMe over Ethernet configurations.

Customers who are counting on NVMe and NVMe-oF need consistent high performance and reliability. NVMe-oF delivers these capabilities and it also seems to be the best channel for delivering mixed SCSI / NVMe environments. Support for legacy and modern protocols is critical, given that network infrastructures tend to evolve and change slowly over time. Customers want to use their existing investment in networking hardware and cable infrastructure.

Another key driver is the increase in demand for high-velocity analytics and artificial intelligence. Disaggregation of storage across scale-out clusters and to the cloud can hurt high-velocity analytics initiatives. The clusters add latency. Centralizing storage, at least for primary processing, reduces latency and makes finding data easier. Fibre Channel, combined with NVMe all-flash, enables highly scalable infrastructures without disaggregation.

A new driver is the repatriation of workloads from the cloud. Organizations are concluding that they were too aggressive in their cloud migration and cloud-first strategies. As a result, 41% of businesses brought at least one workload back from the cloud, according to an ESG study. Organizations often underestimated how sensitive their workloads were to the performance and consistency that on-premises storage architecture brings.

The Future of FC

Storage Switzerland believes that as technology continues to reduce latency in the infrastructure, bandwidth speed and total capacity of the network becomes increasingly important. With less latency, workloads are free to send and receive more data and more workloads can share connections. Gen 7 (64GFC) provides the fastest single lane networking speed available while still being backwards compatible with two generations of hardware and cabling. We expect to see Gen 7 products in 2019.

In addition to Gen 7, FC-NVMe-2 will soon become a published standard. FC-NVMe-2 provides refinements to the existing FC-NVMe standard. It improves error recovery to a more granular level, which enables the network to respond and correct minor error conditions instead of forcing an NVMe subsystem to disconnect/reconnect. The result is even more predictable performance.

StorageSwiss Take

Fibre Channel is alive and well. Much of its recent success is driven by organizations with an FC investment having the confidence to continue to leverage and upgrade the technology. For organizations with the experience, FC presents a very strong value proposition. For those that don't have an FC investment or have transitioned out, it may be time for another look as it provides value for most legacy and modern workloads.

FIBRE CHANNEL NEW TECHNOLOGIES: FC-NVME-2

By Rupin Mohan, FCIA Marketing Chairman; Director R&D and CTO, Hewlett-Packard Enterprise

Fibre Channel is a serial point-to-point protocol that transfers a ton of data super reliably using light over fibre cables. Data is transferred from one port to another from the initiator port on the server to the destination port on the storage array.

A switching fabric allows communication among more than just initiator and target ports by introducing switching ports in the data path. Even if switch ports are in the data path, Fibre Channel is still a point-to-point protocol. The data transfers are reliable because just like an airplane only takes off after it has confirmed a landing spot at the destination airport, Fibre Channel data packets are only transmitted after a destination port confirms it has enough data buffers to receive the packet.

Fibre Channel does a great job of delivering data reliably. It doesn't matter if the data packets are SCSI or NVMe. NVMe over Fibre Channel (FC-NVMe) defines the mapping of NVMe over Fabrics (NVMe-oF) to the Fibre Channel protocol.

The I/O operation defined by FC-NVMe is mapped into a Fibre Channel Exchange. A Fibre Channel Exchange carrying information for an NVM Express over Fabrics I/O operation is an FC-NVMe Exchange. In simple English, the initiator ports sitting inside servers and the destination ports on the storage arrays establish their point-to-point connections and transfer data back and forth using Fibre Channel exchanges.

In order to provide a more reliable and solid base platform for NVMe over Fabrics, FC-NVMe-2 will introduce optimizations on how Fibre Channel Exchanges carry NVMe traffic. These optimizations include:

Exchanges are given some more time before getting terminated

FC-NVMe associations are terminated only after transmitting proper ABTS (Abort Sequence) so that all resources associated with this exchange are recovered before the exchange or the association is completely terminated.

Exchange association identifiers are reused more efficiently after exchanges are terminated

By properly terminating an outstanding exchange, as mentioned above, all the resources associated with the terminated exchange can be reused efficiently

Enhancements when supported by both initiator and target ports including:

Support first burst, further optimizing FC-NVMe data transfers

- Initiator may choose to perform faster write operations by sending first data without waiting for a transfer ready (XFER_RDY) message from the target. This helps in faster data transfers as long as the first burst data is within the limits of the agreed upon burst size.

Sequence Level Error Recovery (SLER), which allows higher level exchange recovery

- Sequence-level error recovery allows error recovery by using sequence re-transmissions. This is accomplished via some new commands (FLUSH and Responder Error Detected - RED) exchanged between initiator and target ports to indicate, and recover from, any sequence level errors during an exchange.

Support confirmed completion

- FC-NVMe-2 will define a mechanism so that the target and initiator ports can use special messages to determine successful completion of all sequences within a given exchange.

End-to-end data protection

Exchanges are retried when there is an error in data transfer

- As mentioned above, confirmed completion features when used together with SLER will result in better error handling and recovery.

Fibre Channel exchanges and sequences are the foundation of the protocol and with these new features, FC has built even a stronger foundation with even more reliability for the next generation storage protocol, NVMe over Fabrics. With all these enhancements, it's difficult to dispute that Fibre Channel is the most reliable and high-performance fabric protocol for NVMe packets.

THE 2019 FIBRE CHANNEL ROADMAP

By Craig Carlson, FCIA Board Member; Senior Technologist, Marvell Semiconductor Inc.

When companies invest in a technology, they want to know that they will get a return on their investment for years to come. Fibre Channel has had a very accurate roadmap for over a decade, showing the past, present and future of the Fibre Channel physical layer. Fibre Channel has been progressing since 1996 by doubling the data rate every few years and the roadmap shows the progression will continue far into the future. Fibre Channel continues to outpace other physical layer technologies like Ethernet and will continue to surpass them in speed.

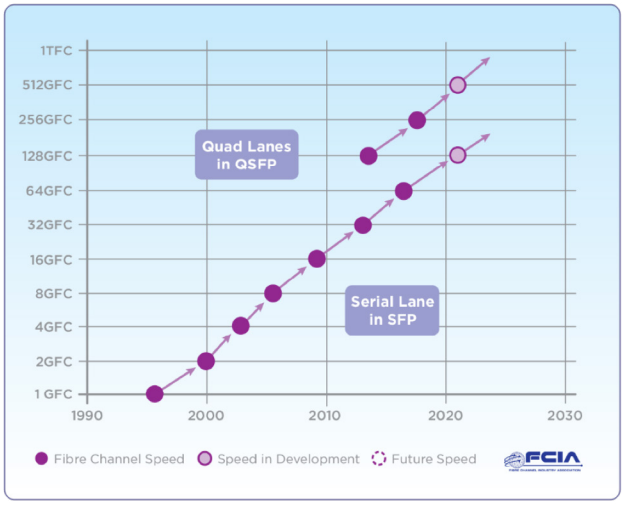
The ANSI INCITS T11.2 Task Group (T11.2), the standards body that defines Fibre Channel speeds, finished 64GFC in 2018. 64GFC runs 9% faster than 50GbE and has been defined for a Bit Error Ratio (BER) of 1E-15 that is 1,000 times better than Ethernet that has a 1W-12 BER. 64GFC products are expected to ship in 2019/2020. T11.2 is also working on 128GFC that runs 9% faster than 100GbE. 128GFC is expected to be completed in 2021 with products shipping in 2022. The Fibre Channel physical layer will continue to leverage the developments in the Ethernet physical layer and exceed them.

An accurate roadmap provides a reliable guide for suppliers, manufacturers and distributors of products to plan their product development and release cycles. The features and timing of the technology migration reflected in the roadmap are based on open standards that are technically stable and complete. Some technology developments outlined in reliable roadmaps are required building blocks for product development. For example, lasers in optical modules need to be developed before transceiver modules used in a switch or host bus adapter. With a solid roadmap and standards, multiple companies can develop products in parallel that will eventually interoperate when they reach the market.

FCIA's Roadmap Committee produces the FCIA Speedmap in concert with T11.2. The resulting roadmap is the refined product of an intense iterative process that pinpoints highly attractive market propositions balanced with sound engineering feasibility. It becomes the official FCIA Speedmap and MRDs (Marketing Requirement Documents) for T11.2's map of speeds and timelines. The MRDs define sets of features and benefits that are not only feasible within the Speedmap timelines, but also result in actual products delivered in the prescribed timeframe that realize massive market success.

FCIA's roadmap has helped the industry see the future of Fibre Channel for over 15 years. Fibre Channel has always had a clear road ahead where the link speeds double every 3-4 years when the speeds can be cost-effectively doubled. Figure 1 shows the history of Fibre Channel speeds and future speeds after 2020.

Figure 1: Fibre Channel Speeds



[1]*At the time of this article, the exact 128GFC design parameters have not been finalized and may change.*

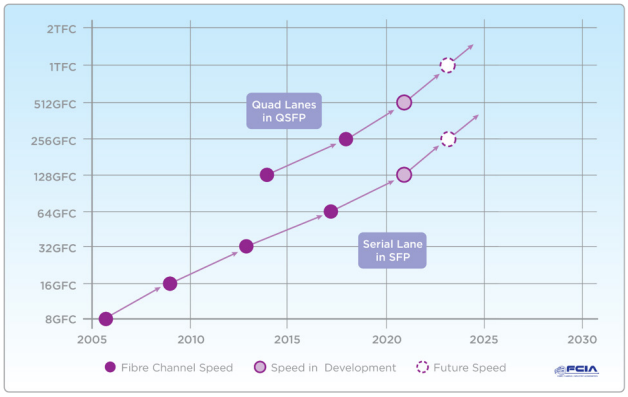
Figure 1 also shows how Fibre Channel initially used only serial speeds for the first five generations. These serial speeds have used the venerable Small Form Factor Pluggable (SFP) module. The sixth generation of Fibre Channel, known as Gen6 Fibre Channel, uses the SFP28 (an SFP that runs at 28Gb/s) for 32GFC as well as the Quad Small Form Factor Pluggable (QSFP28) module for 128GFC. T11.2 just finished the seventh generation of Fibre Channel speeds that will continue this tradition with 64GFC in an SFP and 256GFC in a QSFP. The project for the eighth generation of Fibre Channel that supports 128GFC in the SFP is underway and is keeping pace with 100 Gigabit Ethernet (100GbE) in an SFP module.

The Fibre Channel Roadmap doesn't stop there. In Figure 2, the roadmap extends to Terabit Fibre Channel (1TFC) – that's almost 1,000 Gigabits of data per second. Following the 1X/4X lane paradigm, Fibre Channel and Ethernet plan to double individual lane speeds repeatedly over the next decade. With Fibre Channel's focus on storage in the data center, Fibre Channel will continue to standardize speeds at approximately the same time as Ethernet, but Fibre Channel speeds will be 9% faster. While Fibre Channel doubled speeds from 28Gb/s to 56Gb/s in 2017, Ethernet plans to double 25Gb/s to 50Gb/s in 2018. The trend will continue with Fibre Channel lanes doubling to 112Gb/s and then 224Gb/s. When 4 lanes of these speeds are aggregated, the combined speeds will deliver almost a terabit/second of data for what will be known as Terabit Fibre Channel (1TFC).

While Fibre Channel standards are completed in advance of products being released by at least a year, some Ethernet products are released before the Ethernet standard is ratified. This means that Ethernet products of similar speeds are released at about the same time as similar speed Fibre Channel products. For example, 50GbE products running at 53.125Gb/s and 64GFC products running at 57.8Gb/s are both expected to be widely available in 2019/2020 for the first time. High-speed Ethernet and Fibre Channel products are basically running on similar physical layers.

The physical layers of Fibre Channel and Ethernet are marching at a similar pace now. While Fibre Channel has continuously doubled speeds from generation to generation, Ethernet used to grow by a factor or 10 until 40GbE came along. 40GbE, which is based on 4 lanes of 10G technology, broke

Figure 2: Future Speeds for Fibre Channel



the 10X paradigm and opened the door to more moderate steps in speed. Similar to technology progressions like Moore's Law and storage capacity, doubling of lane rates is the new norm. Individual lanes can then be grouped together to form new speeds. While Ethernet continues to use up to 16 lanes for 400GbE router applications, only 1X and 4X lanes are shown in the Fibre Channel Roadmap because these are the only relevant speeds for storage area networks (SANs).

The Fibre Channel Roadmap has been printed as a physical, folding roadmap and an electronic version can be downloaded at: https://fibrechannel.org/roadmap/. The backside of the map shows how Fibre Channel is used in data centers around to world to store and replicate data. Fibre Channel continues to grow and provide the most cost-effective and reliable links for SANs.

Besides the roadmap, the FCIA Roadmap subcommittee develops the MRD for new speeds like 128GFC. Important elements defined in the MRD include backward compatibility with previous speeds. For instance, just like 1/2/8/16GFC, and 32GFC edge connectivity, 64GFC and 128GFC are required to be backward compatible at least two generations. These speeds are auto-negotiated with no user intervention required, - i.e., 32GFC ports will automatically run at 8GFC and 16GFC, while 64GFC will automatically run at 32GFC and 16GFC. 128GFC continues Fibre Channel's long history of ensuring total backward compatibility by also operating at 32GFC or 64GFC. This important level of backward compatibility has been and will continue to be a major benefit in Fibre Channel's continued success.

FIBRE CHANNEL'S FUTURE IS BRIGHT IN MEDIA AND ENTERTAINMENT

By Joseph Kimpler, Strategic Alliances, ATTO Technology, Inc.

Despite the push for Ethernet adoption in the Media and Entertainment industry, Fibre Channel storage network connectivity remains an essential enabler of today's content creation and media workflows.

As video resolution and frame rates continue to grow, so does Fibre Channel network storage within the Media and Entertainment market. Coughlin Associates, publisher of the Media and Entertainment Storage Report, projects close to 10% growth in Fibre Channel ports in 2019 in Media & Entertainment applications.

To support demanding new 8K and 4K workflows, system administrations and other IT professionals in Media and Entertainment are choosing to expand and upgrade their existing high-performance, easy-to-manage and well-known Fibre Channel SAN fabrics, rather than add additional performance sensitive traffic to their Ethernet network.

Choosing the Right Network

The choice between using Fibre Channel or Ethernet is largely dictated by whether a dedicated SAN is required and/or desirable. Typically, Ethernet-based SANs are implemented in the context of a converged network or at the minimum sharing of switch ports, although there has been an increased use of dedicated iSCSI fabrics as well. Fibre Channel networks are always utilized as dedicated SANs. For many use cases such as telecom central offices and embedded applications, a dedicated SAN is not an option. In other cases, the mission-critical nature of the application alone justifies a dedicated SAN. Examples of this include billing systems and enterprise resource planning (ERP) systems for Fortune 500 companies and raw content editing and post-production workflows in the Media and Entertainment industry.

Rich Media Content Thrives on Fibre Channel

Technology leaders in Media and Entertainment continue to invest in Fibre Channel because of its proven and unique edge over other networking technologies in terms of rock-solid reliability, unmatched predictable performance and massive scalability.

In today's time-sensitive environments, it's critical to ensure creative professionals have secure and dedicated bandwidth. In post-production, visual effects and animation, there is nothing faster and more reliable than Fibre Channel. With 48% less overhead per frame compared with Ethernet, and the ability to handle a 40% bigger workload without requiring re-transmission or error checking, Fibre Channel is built specifically for low-latency flash storage. It's built on foundational technology with the guarantee data will transmit in order, on time and without corruption.

With Fibre Channel, a SAN administrator can also dedicate ports to ensure adequate bandwidth is available to easily zone a SAN and efficiently divide workloads. Fibre Channel provides better security because permissions can be allocated and cross traffic is eliminated. With the risk of a data breach significantly reduced, entertainment organizations have the peace of mind that their latest project will not leak early and jeopardize their business.

New leading-edge media technologies like 8K and 4K video, virtual reality, augmented reality formats, and other visual enhancement technologies such as high dynamic range (HDR), high frame rate (HFR) and wider color gamut, demand new, higher performance delivery requirements to support workflows. With 16 times the resolution of 1080p HD, 8K video, in particular, creates one of the toughest technical challenges for studios. This is where Gen 6 Fibre Channel delivers the most robust solution in the industry with 32 Gbps performance, low latency and the flexible scalability to handle complex workflows and the growing storage requirements for future Media and Entertainment projects.

Unpacking the post-production workflow reveals multiple steps taking place in the processing of content to support the editing that occurs from distribution, production, and data protection. The workflow demands of creating, transferring, duplicating, storing, securing, and archiving data require a reliable network that guarantees frames are not dropped.

Other examples of use cases requiring a high-performance network include:

- **Video ingest** – Capturing, transferring or importing different types of video, audio or image media into an editing program
- **Mastering and finishing** – Color correction, checking for gaps, bad transitions, visual errors, broadcast legalization or finessing of graphics
- **Playout and distribution** – Servers for broadcasting have no-fail commercial requirements for no dropped frames
- **Digital asset management** – An integral part of today's push in the Media and Entertainment industry to provide better protection and utilization of media assets
- **Accessing digital assets** – Retrieving content stored on tape, HDDs, or SSDs that are transitioning to advanced storage array technology
- **Data center applications** – Content analytics deliver insight into the amount of content being created, the nature of that content and how it's used to optimize workloads and time to market
- **High power server connectivity to all-flash arrays** – Supports enterprise applications to combine business intelligence and business analytics practices and apply them to digital content

This is why Fibre Channel is the storage enabler the world's leading media and film companies have relied on for decades. Gen6 32GFC is the most advanced storage networking technology purpose-built to address the most challenging Media and Entertainment workloads.

Looking Ahead

Since its inception over two decades ago, Fibre Channel has been the fabric of choice for SANs. With over 120 Million ports shipped, an estimated 46M Fibre Channel ports are currently in operation today, most of which provide up to Gen6 Fibre Channel. This represents not only a massive base of Fibre Channel already installed but also a significant financial investment. This in-place infrastructure provides a solid foundation for the adoption of technologies like Gen 7 64GFC and NVMe over Fibre Channel.

Fibre Channel SANs have been the best choice for storage architects and will continue to be the lowest risk and highest performing option. Because Fibre Channel SANs are dedicated to storage traffic, they can scale and grow without impacting performance. Therefore, the future for Fibre Channel is very bright within the Media and Entertainment industry!

For more information, check out interviews with experts in Media and Entertainment as they discuss why Fibre Channel is the key to making 8K and 4K media production possible or read Fibre Channel Connectivity in Modern Content Creation Workflows by Jim McKenna, Facilis Technology, for an in-depth analysis of Ethernet versus Fibre Channel in rich media environments.

SECURING FIBRE CHANNEL SANS WITH END-TO-END ENCRYPTION

By Robert Friend and Nishant Lodha, Marvell Semiconductor, Inc.

Fibre Channel is a purpose-built and proven storage network designed to meet the demands of enterprise data centers that require high availability, low latency, extreme reliability and seamless scalability. Fibre Channel (FC) SANs are deployed in over 90% of Fortune 1000 customer data centers that run mission-critical storage workloads. With ever increasing threat vectors both inside and outside the data center, a compromised customer dataset can quickly result in a torrent of lost business data, eroded trust, significant penalties, and potential lawsuits. There are potential vulnerabilities at every point in the enterprise infrastructure which requires data to be secured not only when it leaves the data center or is exposed to the internet, but every time it leaves a server or the storage media.

Existing SAN Security Mechanisms

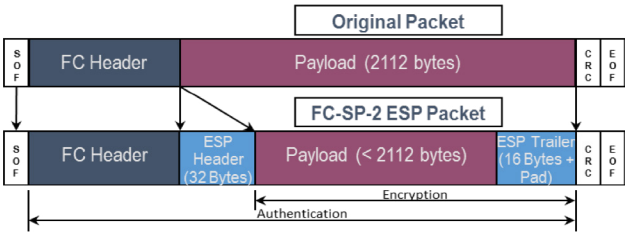
Fibre Channel SANs are inherently secure but are increasingly facing new and renewed threats. This is driving the industry to do more to secure Fibre Channel. The Fibre Channel protocol and a majority of Fibre Channel devices -- from HBAs to switches and storage devices, implement various security mechanisms ranging from access control via zoning, LUN Masking, and the security that physical segregation of storage and local area networks brings. However, with the increased risk of today's multi-tenancy environments that share Fibre Channel SAN resources across an increasing amount of host applications combined with increasing occurrences of insider attacks , make additional layers of protection required. In addition, government regulations including HIPAA, GDPR and ISO27001 A.10 increasingly require that transmission and storage of customer data be secured.

The level of security that will be required for Fibre Channel SANs is more than just encrypting storage media, as this only secures data against physical theft from the data center and does not protect against vulnerabilities while the data is in transit between host and storage media. During normal operations, data leaves shared storage devices unencrypted, which may pose a security risk. Adding defense in depth to the Fibre Channel SANs is prudent and provides excellent protection of mission-critical data that frequently traverse the Fibre Channel storage area network.

Fibre Channel Security Protocol FC-SP-2 standard provides the protocols and methods to extend the decades of proven security and storage networking technologies to the next level – encryption of data in flight.

Encrypting with Fibre Channel Security Protocol

Fibre Channel - Security Protocol (FC-SP-2), a stable and published standard, defines a security mechanism for FCP (Fibre Channel Protocol), FC-NVMe (NVMe over Fibre Channel) and FICON (Fibre Connection), developed by the Technical Committee T11 of the International Committee on Information Technology Standards (INCITS). It provides a security framework which includes authentication (using Diffie-Hellman Challenge Handshake Authentication Protocol (DHCHAP) or IKEv2), cryptographically secure key exchange, and cryptographically secure communication between Fibre Channel devices. The standard defines how to protect data in flight within a Fibre Channel SAN. It does not address the security of data at rest (in a storage device), for which other mechanisms already exist.



Within FC-SP-2, ESP_Header is a security protocol for Fibre Channel frames that provides origin authentication, integrity, anti-replay protection, and confidentiality. FC-SP-2 has adapted the IKEv2 protocol (used for IPsec) to provide authentication of Fibre Channel entities and setup of security associations. Within this framework, a Fibre Channel device can verify the identity of another Fibre Channel device and establish shared secrets that will be used to negotiate security associations for security protocols applied to Fibre Channel frames and information units.

Protections Provided by the Fibre Channel Security Protocol

When implemented, the FC-SP-2 standard will enable the following additional protections for Fibre Channel SANs:

- Origin authentication - verification that the traffic came from a given endpoint.
- Integrity assurance – assurance that the data transmitted was not tampered with before being received at the other end.
- Anti-replay protection – avoids a network attack in which a valid data transmission is maliciously or fraudulently repeated.
- Confidentiality – only the sender and receiver have access to the data contents of the frame.

Ecosystem and Market Dynamics

Encryption of data in flight seamlessly secures the entire SAN and is critical not only within, but also between, data centers for mirroring, backups, and remote replication to disaster recovery sites. Today, most Fibre Channel switches implement encryption for the data traffic that flows between Inter-Switch Links (link encryption), but an end-to-end solution between host/HBAs and storage devices is not yet generally available. Increased occurrences of insider attacks, theft of data while in transit, as well as government regulation is driving the Fibre Channel industry to productize an end-to-end Fibre Channel encryption and authentication implementation. It is expected that such implementations will work with existing SAN switch infrastructure. As defined in the FC-SP-2 specifications, payloads are encrypted, but the Fibre Channel header is sent in clear text, enabling encryption of data in flight to function with existing SAN switching.

A true secure SAN is one with end-to-end encryption and authentication! We expect that Fibre Channel HBAs with FC-SP-2 compliant, fully offloaded, end-to-end encryption capabilities will be generally available in early 2020.

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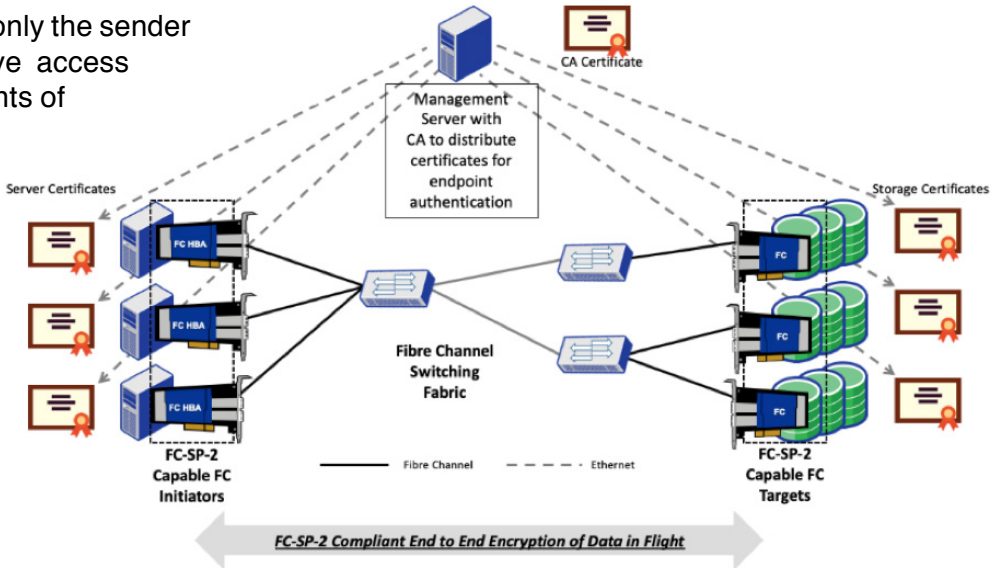
[1] *https://fibrechannel.org/wp-content/uploads/2018/08/FCIA_SolutionsGuide2018_web.pdf*

[2] *https://www.forbes.com/sites/realspin/2016/08/30/the-future-of-insider-threats/#7e5270a47dcb*

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