# FIBRE CHANNEL SOLUTIONS GUIDE

2017


fibrechannel.org

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# Fibre Channel & FCoE

*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.

Today, Fibre Channel technology continues to be the data center standard for storage area networks and enterprise storage, with more than 80 percent market share.

## CONTACT THE FCIA

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# The Solutions Guide Introduction

*Mark Jones, FCIA President, Broadcom Limited*

2017 is poised to be another great year for the Fibre Channel industry. Since the publication of our last FCIA **Solutions Guide** in 2016 there has been both tremendous industry progress and technical developments that will shape the future of the storage industry. The legacy of data reliability, integrity and security have always been the compass by which storage professionals make their choices, and not surprisingly Fibre Channel continues to be the interconnect of choice when those attributes are required.

## Industry Shifts

In the last few years, the big vendor news in the storage industry has been the consolidation of highly-valued storage companies and supply chain vendors by large multi-national corporations. These acquisition targets – with the highest performance, greatest innovation and unique intellectual property – are seen as strategic for companies to offer feature rich, fully developed and reliable portfolio of solutions that discerning datacenter buyers demand.

It could be argued that since these acquisition targets offer high performance all flash storage and are primarily connected to host computers using Fibre Channel interfaces, that Fibre Channel technology has a long and innovative future. The series of acquisitions of Fibre Channel HBA and switch suppliers, all of which are industry pioneers, have been key contributors to the innovation and success of the Fibre Channel industry.

In 2016 the semiconductor company Cavium purchased Fibre Channel HBA supplier QLogic Corporation, in 2015 the semiconductor company Broadcom Limited purchased Fibre Channel HBA supplier Emulex Corporation and (at the time of this writing) plans to purchase leading Fibre Channel switch supplier Brocade Communications. Any concerns about post-acquisition decommissioning of popular technologies have been unwarranted: these business units all continue to make major contributions to the long-term future developments of Fibre Channel and the industry. On the contrary, the investment by very successful semiconductor suppliers is a strong vote of confidence into the long term prospects of the Fibre Channel technology.

In 2017 we have also seen major milestones in the adoption of Fibre Channel technology. Leading datacenter analyst firm Dell'Oro (1) estimates that 113 million ports of FC switches and adapters have shipped since 2001 and estimate that 46.2 million

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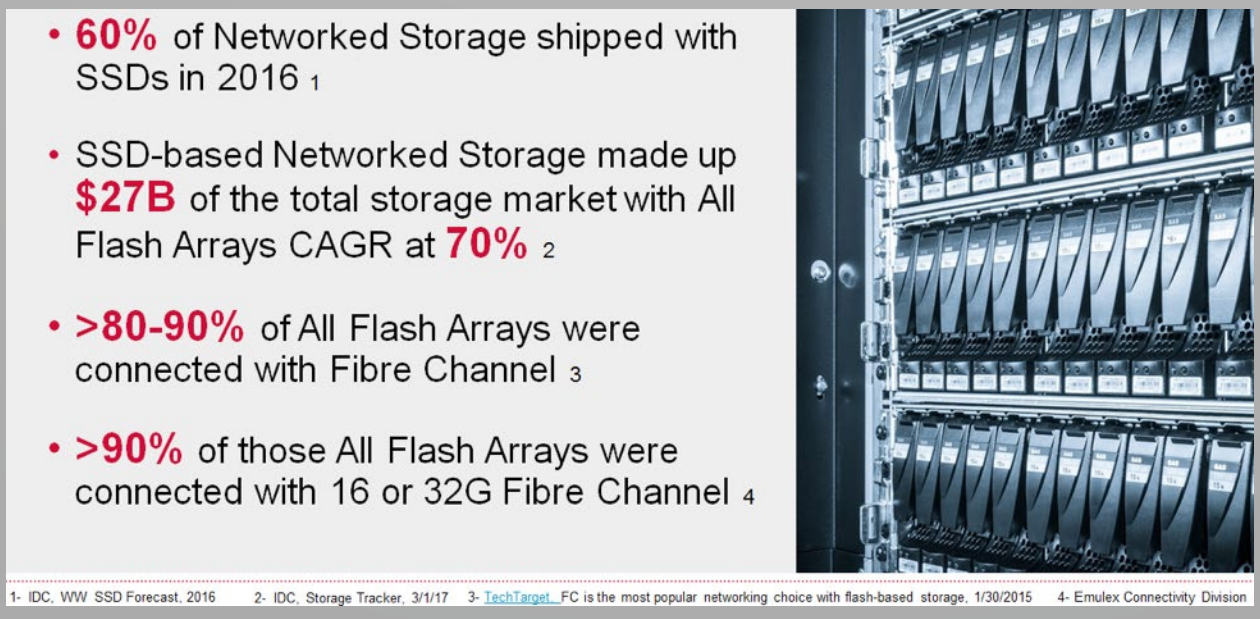

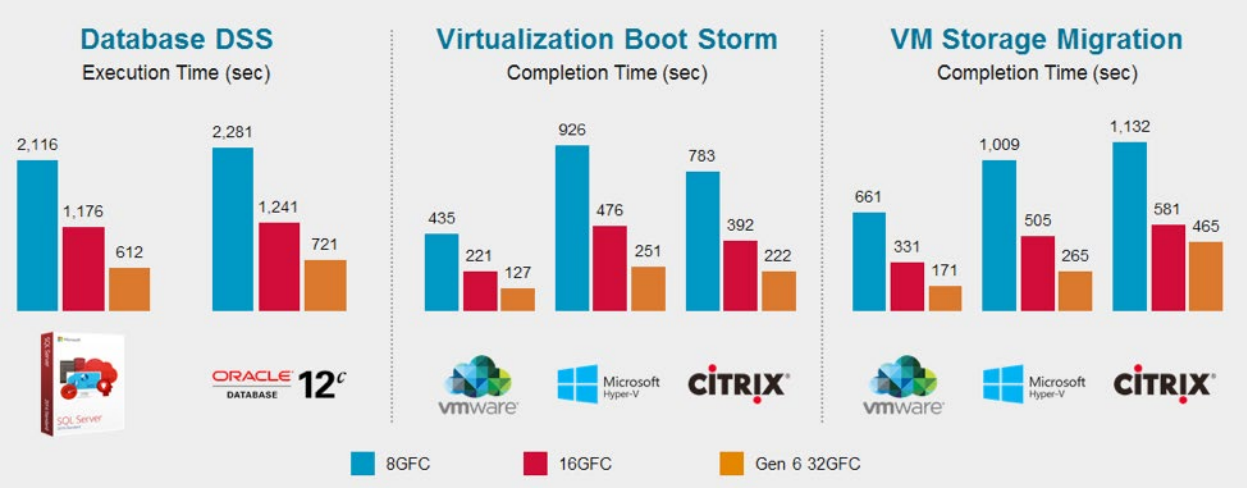


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ports are still currently in operation, this number continues to grow from previous years. Also of note is that we are seeing that 16GFC ports are now shipping in greater numbers than 8GFC, which is typical for a transition cycle when new speed increases are introduced. 32GFC shipments are also now ramping with strong growth expected, we now have reached the milestone of having multiple vendors shipping 32GFC in the Server, Switch and Storage ecosystem segments. This continued strong demand is no surprise as analyst firm IDC (2) has reported that Enterprise storage capacity has grown 18.3% year over year.

## The News Flash on Flash

One of the major shifts in the enterprise storage market has been the shift from spinning hard disk technology to flash storage. Storage arrays with flash storage technology are often referred to as All Flash Arrays (AFA) and have redefined the fundamental expectations of accelerating datacenter application performance.

AFA's break the notion that you need high spindle counts and huge configurations to achieve high performance – that much is well-known. However, coupled with current server technology that house hundreds of processor cores in a small footprint, you can start to see that the communication link begins to be the critical component for achieving maximum system-wide performance. Nearly all AFA products in the marketplace come equipped with Fibre Channel connectivity, and even those offered with mixed protocol options are usually implemented using Fibre Channel.

With Gen 6 32GFC Fibre Channel now shipping broadly datacenter application performance can now take full advantage of all the performance that Gen 6 has to offer, Chart 1 offers a few examples of the performance impact that Gen 6 has to offer.

**The Fibre Channel Pedigree**

The completion of the first Fibre Channel standard was for 1GFC and completed in 1997 by the T11 technical committee of the International Committee on Information Technology Standards (INCITS). Since that time a new standard has been developed every 3-5 years that effectively doubled the speed.

Never has it been more necessary. To keep up with the development pace of server performance, as well as the next generation of flash storage, the next generation of Fibre Channel is already being developed within T11. 64GFC is expected to be technically defined this year and will be the fastest single lane networking technology available for storage. Moreover, because it is Fibre Channel, it will be defined with all the features that have made previous generations successful.

One of Fibre Channel's major appeal is its consistency; a key feature that has made it a commercial success is its design requirement to be backwards compatible at least two generations. Customers investing in the latest iteration of Fibre Channel today can deploy it and expect communication compatibility with the Fibre Channel investments they made ten years ago or more. This kind of investment protection has made Fibre Channel a financially smart choice for corporations to plan capital resources for their storage growth needs.

## Opening Up The Conversation

Unfortunately, as ubiquitous as Fibre Channel is inside of Data Centers, it is not always easy to learn about it. There are very few university courses on storage networks, unlike programming languages, virtualization, open source computing, and the like. In fact, most of the Fibre Channel administrators learned "the hard way," through trial-by-fire and tribal knowledge.

In 2017, the FCIA began working to change that

by beginning a series of instructional webinars for data center practitioners. Working in conjunction with BrightTalk, the FCIA has created a number of instructional and educational webinars to foster understanding of not only the fundamentals of Fibre Channel, but also advanced topics such as FC-NVMe, interpreting the Speedmap (see Scott Kipp's article in this Solution Guide as well), and many more. All of these webinars, blogs, and articles can be found at FCIA's website: fibrechannel.org.

## Speaking of the Future…

FC-NVMe is the Fibre Channel standard that maps Fibre Channel to NVMe over Fabrics, and is nearing completion and will be technically stable in 2017. This new standard promises to increase network performance and lower latency to NVMe native devices when compared to the more traditional SCSI-based storage devices. Far from biding their time, vendor companies are investing heavily in developing robust solutions for customer deployments.

On May 21, 2017 the FCIA and its member companies completed its first **FC-NVMe Plugfest** at the University of New Hampshire InterOperability Lab (UNH-IOL). The focus of the Plugfest focused on device conformance to the proposed FC-NVMe standard and device interoperability. Fibre Channel has developed a reputation for interoperability among vendors, reliability and robustness. After 37 plugfests over the last eighteen years the Fibre Channel vendor community has learned that there is no better validation of a technology standard and test for product readiness than to get all the vendors together and test what works, fix what doesn't, and repeat.

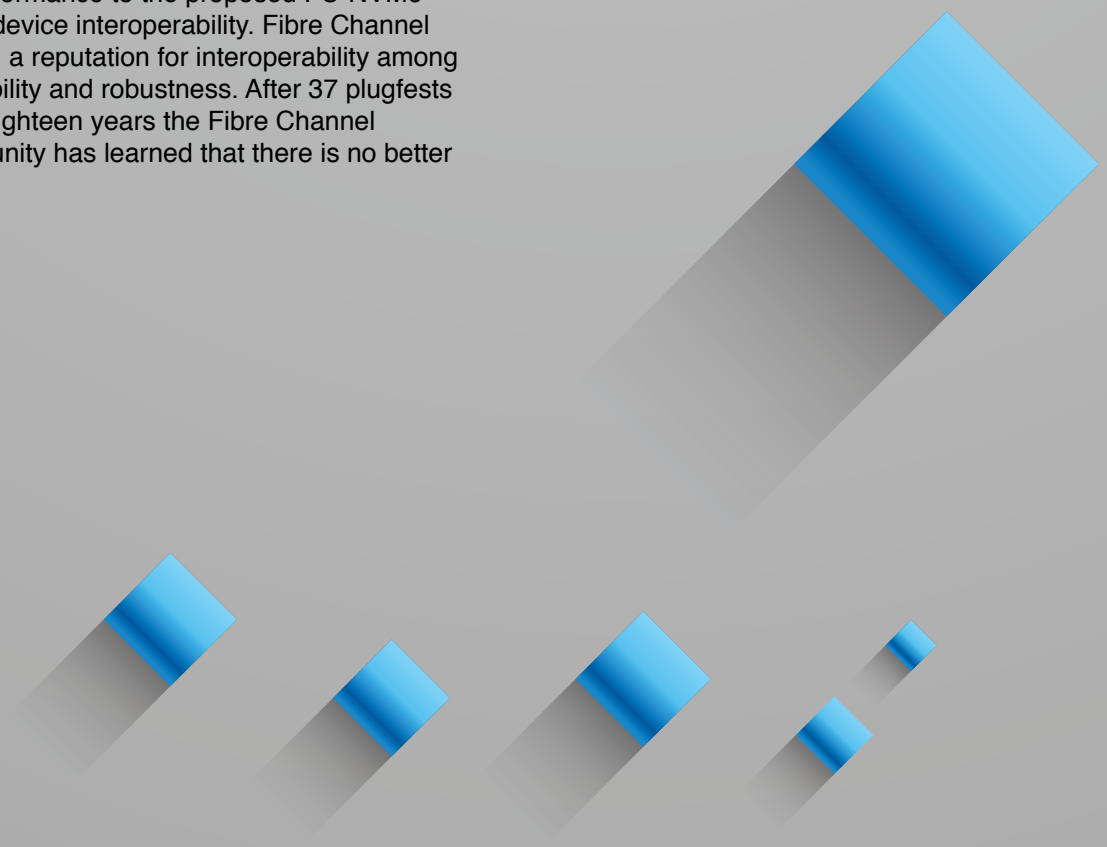
## … And Beyond!

2017 is poised to be another great year for the Fibre Channel industry. The completion of numerous new standards will set the course of Fibre Channel until the end of the decade. You can expect to see more plugfest readiness events for FC-NVMe products that will likely begin to be commercially available by the end of the year.

If you are interested in learning more about the Fibre Channel industry, the technology, direction and roadmap please visit **FibreChannel.org**. Also be sure to check out the **FCIA Brighttalk Webinar** series for both live and recorded webcasts of timely industry content and education.

*Footnotes*

1. Dell'Oro May 2017
2. IDC **Worldwide Quarterly Enterprise Storage Systems Tracker** Press Release March 3, 2017



# The Fibre Channel Roadmap

*Scott Kipp, Brocade*

The heart and soul of any technology, and the industry association that stewards the technology, is its technology roadmap. Just like the term suggests, a roadmap shows not just the history of a technology, but also is a guide to where it is going and when it is going to get there.

The Fibre Channel Industry Association's roadmap has helped the industry see the future of Fibre Channel for over 15 years. Fibre Channel has always had a clear vision of the 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 the future speeds through 2020.

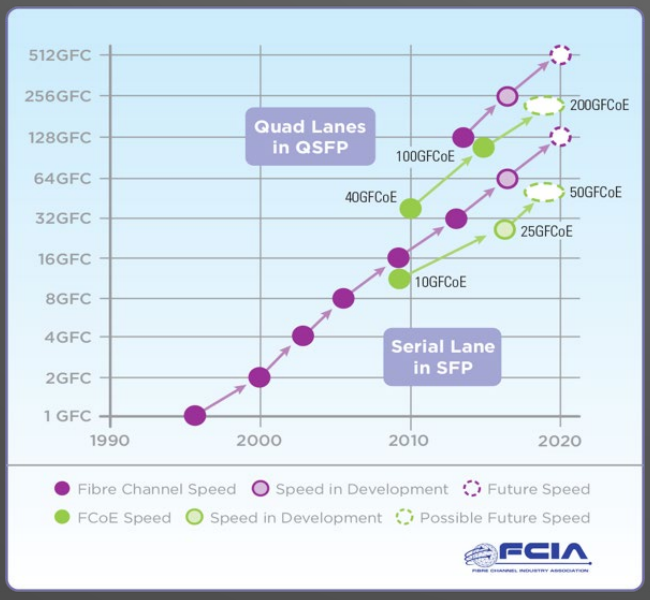



*Figure 1: Fibre Channel Speeds*

Figure 1 shows how Fibre Channel has traditionally used only serial speeds for the first several generations. These serial speeds have used the venerable Small Form Factor Pluggable (SFP) module. The current 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. The T11 INCITS technical committee is currently defining future generations of Fibre Channel speeds that will continue this tradition with 64GFC in an SFP and 256GFC in a QSFP.

Of course, Fibre Channel is more than just the physical link between devices, it is also the protocol by which storage traffic is transported across the Data Center. As a result, the Fibre Channel industry has long-embraced servers connecting to Fibre Channel storage via Ethernet with Fibre Channel over Ethernet (FCoE). FCoE uses the Ethernet physical layer and runs Fibre Channel frames and protocol over that physical layer of Ethernet.

These 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 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 router applications, only 1X and 4X lanes are shown in the 2015 Fibre Channel Roadmap because these are the only relevant speeds for SANs.

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 odd comparison of standards and products means that Ethernet products of similar speeds are released at about the same time as similar Fibre Channel products. For example, 25GbE/100GbE products running at 25.78125 Gb/s and 32GFC/128GFC products running at 28.1Gb/s began to be widely available in 2016 for the first time. High speed Ethernet and Fibre Channel products are basically running on similar physical layers.

The Fibre Channel roadmap doesn't stop there. In Figure 2, the roadmap extends to Terabit Fibre Channel – that's almost 1,000 Gigabits of data per second. Following the 1X/4X 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 before Ethernet.

While Fibre Channel will double speeds from 28Gb/s to 56Gb/s in 2017, Ethernet plans to double 25Gb/s to 50Gb/s between 2018 and 2020. 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).

## The Making of a Roadmap

An accurate roadmap provides a reliable guide for suppliers, manufactures and distributors of products to plan their product development and release cycles based upon the features and timing of the technology migration reflected in the roadmap, 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 the transceiver modules can be developed that will eventually be used in a switch or host bus adapter.

FCIA's Roadmap Committee produces the FCIA Speedmap in concert with the ANSI INCITS T11.2 Task Group, the standards body that defines Fibre Channel speeds. Since FCIA meets at the T11 meetings, and its roadmap committee includes many of the key T11.2 standards engineers as well as key Fibre Channel supplier technical engineering and marketing experts, the resulting roadmap is the refined product of an intense iterative process that pinpoints highly attractive market propositions balanced with sound engineering feasibility.

Other important elements defined in the MRD include backward compatibility. For instance, just like 1GFC, 2GFC, 4GFC, and 8GFC edge connectivity, 16GFC and 32GFC are required to be backward compatible at least two generation. These speeds are auto-negotiated with no user intervention required, - i.e., 16GFC will automatically run at 4GFC and 8GFC, whilst 32GFC will automatically run at 8GFC and 16GFC. 128GFC continues Fibre Channel's long history of ensuring total backward compatibility by also operating at four separate lanes of standard 16GFC or 32GFC or any combination of the two. This important level of backward compatibility has been and will continue to be a major benefit in Fibre Channel's continued success.

The end result is an official FCIA Speedmap and Marketing Requirement Documents (MRDs) that become T11.2's map of speeds and timelines. The MRDs define sets of features and benefits that are not only feasibly doable within the Speedmap timelines, but also results in actual products delivered in the prescribed timeframe that realize massive market success.

The Fibre Channel Roadmap has been printed as a physical, folding roadmap and an electronic version can be downloaded at: [http://fibrechannel.org/roadmap.html](http://fibrechannel.org/roadmap.html).

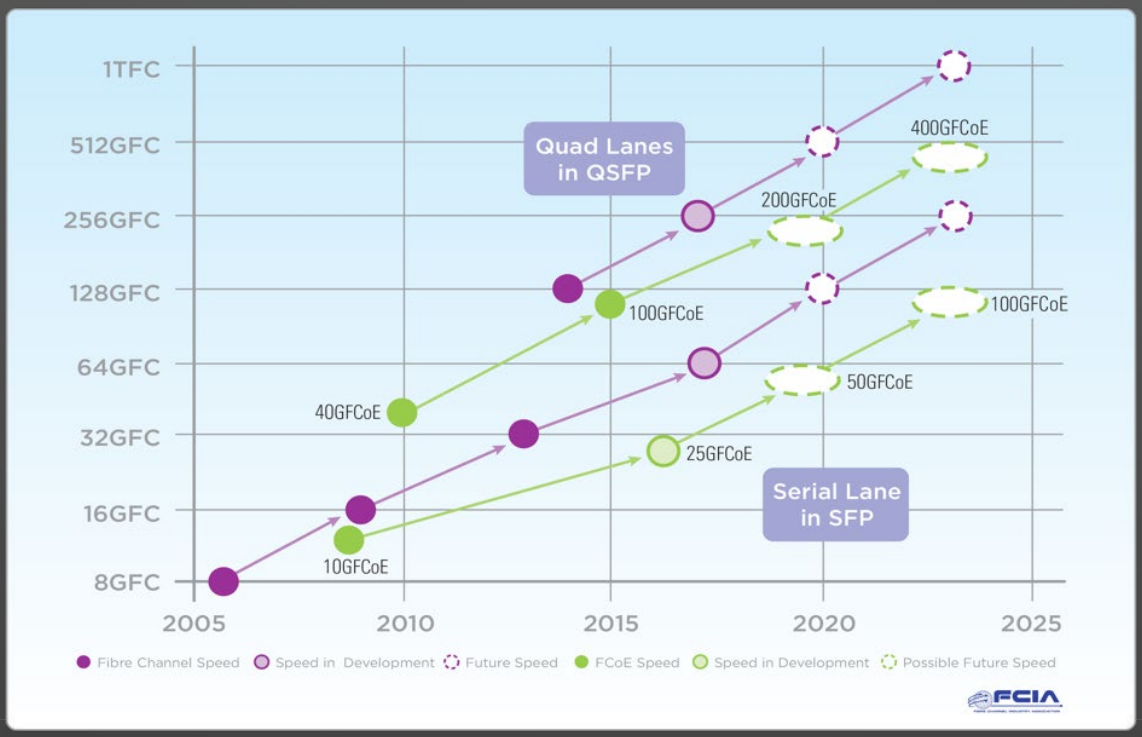



*Figure 2: Future Speeds for Fibre Channel and Ethernet*

# Storage Fabric Options with NVMe

*Rupin Mohan, HPE*

The SCSI protocol has been the bedrock foundation of all storage for more than three decades and it has served (and will continue to serve) customers admirably. SCSI protocol stacks are ubiquitous across all host operating systems, storage arrays, devices, test tools, etc. It's not hard to understand why: SCSI is a high performance, reliable protocol with a comprehensive error and recovery management mechanisms built in.

Even so, in recent years Flash and SSDs have challenged the performance limits of SCSI as they have eliminated the moving parts: they do not have to rotate media and move disk heads. Hence, what you find is that traditional max I/O queue depth of 32 or 64 outstanding SCSI READ or WRITE commands are now proving to be insufficient, as SSDs are capable of servicing a much higher number of READ or WRITE commands in parallel. In addition, host operating systems manage queues differently, adding more complexity to fine-tuning and potentially increasing performance in the SCSI stack.

To address this, a consortium of industry vendors began work on the development of the Non Volatile Memory Express (NVM Express, or NVMe) protocol. The key benefits of this new protocol is that a storage subsystem or storage stack will be able to issue and service thousands of disk READ or WRITE commands in parallel, with greater scalability than traditional SCSI implementations. The effects are greatly reduced latency as well as dramatically increased IOPs and MB/sec metrics.

## Shared Storage with NVMe over Fabrics

The next hurdle facing the storage industry is how to deliver this level of storage performance, given the new metrics, over a storage area network (SAN). While there are a number of pundits forecasting the demise of the SAN, sharing storage over a network has a number of benefits that many enterprise storage customers enjoy and are reluctant to give up. These are:

- More efficient use of storage, which can help avoid "storage islands"
- Offering a full featured, mature storage services like snapshots, backup, replication, Thin-provisioning, de-duplication, encryption, compression, etc.
- Enabling advanced cluster applications
- Multiple levels of disk virtualization and RAID levels
- Offering no single point of failure
- Ease of management with storage consolidation

The challenge facing the storage industry is to develop a really low-latency SAN that can potentially deliver improved I/O performance.

NVMe over Fabrics is essentially an extension of the Non-Volatile Memory (NVMe) standard, which was originally designed for PCIe-based architectures. However, given that PCIe is a bus architecture, and not well-suited for Fabric architectures, accessing large-scale NVMe devices needed special attention: hence, NVMe over Fabrics (NVMe-oF).

The goal and design of NVMe over Fabrics is straightforward: the key NVMe command structure should be able to be transport agnostic. That is, the ability to communicate NVMe should not be transport-dependent.

As of this writing, there are two standardized methods by which NVMe-oF can be achieved:

1. RDMA-based NVMe – This project is working on creating a fabric and related constructs to extend NVMe protocol over a shared Ethernet or InfiniBand network. The same group developing the NVMe PCIe specification is also working on the fabric specification. There are discussions going on in the group around NVMe over TCP/IP and new, emerging network architectures also.

2. NVMe over Fibre Channel (FC-NVMe) – New T11 project to define an NVMe over Fibre Channel Protocol mapping NVMe over Fibre Channel is a new T11 project that has engineers from leading storage companies actively working on a standard. Fibre Channel is a transport that has traditionally solved the problem of SCSI over longer distances to enable shared storage. Fibre Channel, in a simple way, transports SCSI READ or WRITE commands, and corresponding data statuses over a network. The T11 group is actively working on enabling the protocol to compatibly transport NVMe READ or WRITE commands over the same FC transport.

So, how would you compare these two options – here are some thoughts –

| RDMA-Based NVMe-oF | NVMe over Fibre Channel |
|---|---|
| Completely new fabric protocol being developed and standardized | Uses Fibre Channel as a base, existing fabric protocol, shipping, standardized by T11 |
| Standards group dealing with same type of challenges, shipping I/O commands/status, data over distance. | Fibre Channel solved these problems when FCP protocol was developed to ship SCSI commands/ status over distance over a FC network |
| RDMA is available as per protocol | RDMA is not available, uses FCP |
| Zero-copy capability | Zero-copy capability |
| Transport options are iWARP, RoCE (v1 or v2) and even considering TCP/IP | Transport is FC. No changes to switching infrastructure / ASICs required to support NVMe over FC |
| Complex integrated fabric configuration | FC fabrics are well understood |
| Could be lower cost if onboard NIC's on servers and cheap non-DCB switches are used | Higher cost, especially the newer generations of FC are expensive |
| New I/O protocol, New transport | New I/O protocol, Existing reliable transport |
| Lower latency if RDMA is enabled | Latency improvements with hardware assists on Adapters. No RDMA option. |

The FC protocol provides a solid foundation to extending NVMe over Fabrics as it already accomplished extended SCSI over fabrics almost two decades ago. From a practical technical development perspective, the T11 group is so far ahead in developing FC-NVMe because the Fibre Channel protocol was developed from the beginning with the end-to-end ecosystem in mind. Most mission-critical storage systems run on Fibre Channel today, and NVMe is poised to boost those mission-critical capabilities and requirements even further.

Using an 80/20% example, Fibre channel protocols solve 80% of this FC-NVMe over fabrics problem with existing protocol constructs, and the T11 group has drafted a protocol mapping standard and is actively working on solving the remaining 20% of this problem.

In terms of engineering work completed, the Fibre Channel solution solves more than just the connectivity problems; it's laser focused on ensuring administrators and end-users of NVMe over Fabrics are guaranteed the level of quality they've come to expect from a dominant storage networking protocol for SAN connectivity.

## Conclusion

NVMe will increase storage performance by orders of magnitude as the protocol and products come to life and mature with product lifecycles.

There is more to Data Center storage solutions than speeds and connectivity. There is reliability, high-availability, and end-to-end resiliency. There is the assurance that all the pieces of the puzzle will fit together, the solution can be qualified, and customers can be confident that adopting a new technology such as NVMe can come with some well-understood, battle-hardened, rock-solid technology.

With more than 20 years of a time-tested, tried-and-true track record, there is no better bet than Fibre Channel.

# All-Flash Arrays Generate New Interest in NVMe-Ready Fibre Channel

*Celeste Crystal, Brocade*

Digital transformation is driving new requirements for scalability, performance, and high IOPs/low-latency for storage, with access to data becoming more critical than ever. Advanced flash memory technologies are forcing an evolution of storage requirements that must simultaneously enable faster access to data while accommodating growing capacity, all at decreasing costs. By many accounts, all-flash array technologies will dominate the primary storage market by the end of this decade, creating a profound impact in enterprise storage as well as a corresponding pressure on infrastructure.

This proliferation of hybrid-flash and all-flash arrays – and the performance gains, faster IOPs, and lower latency that flash delivers – has resulted in a resurgence of interest in Fibre Channel. According to a recent TechTarget industry survey , 74% of IT professionals surveyed use Fibre Channel today and 86% plan to either increase their use of Fibre Channel or to remain on Fibre Channel, with 59% planning to increase their use of Fibre Channel. The combination of flash storage with Fibre Channel innovation continues to enable enterprise datacenters to keep up with the fastest workloads, especially as network performance increases from 16GFC to 32GFC.

There are key reasons why Fibre Channel commands its time-tested position in data center storage ecosystems:

## Technology Maturity

The world's data centers put their trust in Fibre Channel; 96% of the world's banks, airlines and retailers run over Fibre Channel with over 30 billion transactions per day. For over 20 years, this technology has defined the gold standard in dependable storage traffic.

## Scalability and Flexibility

Fibre Channel is the most scalable storage networking solution available in the world. In fact, a single fabric can enable up to tens of thousands of servers and storage devices, consolidating petabyte-scale storage in a single fabric. As a result, it easily scales to hundreds of thousands of workloads and thousands of storage devices. What's more, Fibre Channel offers multiple configuration options, including point-to-point and switched networks, and can work over long distances for storage extension purposes.

## High Availability, Reliability and Dependability

Since its earliest beginnings, Fibre Channel was designed to meet the requirements of highly demanding storage technology. Most importantly, it was created to address the highly-sensitive nature of mission-critical data needs. When it comes to storage, data loss is an unacceptable risk, and Fibre Channel has excelled by being the leading technology that can constantly meet the challenge of superior reliability and consistency. With its lossless and deterministic characteristics, Fibre Channel was engineered from its inception to ensure throughput requirements and low latency performance.

## Manageability

One of the key advantages of Fibre Channel is the centralized configuration and administration. In Fibre Channel, every device is connected through a coherent fabric, where each switch is aware of the domain topology and has the autonomy of making the most efficient decisions for traffic delivery. This makes manageability easier, because instead of having to "touch" every device in the network, administrators simply enable the fabric to accommodate common rulesets. This enables the entire storage network to be managed as a single system.

Why the renewed interest in Fibre Channel? Fibre Channel technology has recently gained a new surge of interest from shared storage enthusiasts, network

administrators, and the data center infrastructure community at large. New discussions around common data center storage networking protocols are now a top priority due to the rapid adoption of high-throughput flash storage arrays. High-performing, highly reliable, shared storage is essential for large-scale applications to deliver fast access to huge amounts of storage in a cost-effective, highly scalable way – these attributes are where Fibre Channel technology has exceeded benchmarks for decades. And with the advent of even more advanced flash technology and the new potential of blazing fast NVMe performance, an opportunity has opened up for organizations to fully benefit from the exceptional characteristics of high throughput random access, flash memory-based storage arrays with a high performing Fibre Channel infrastructure.

## Fibre Channel Fabrics: Ready for NVMe and the flash future

It's rare when an incumbent technology also has the built-in capability for the next new wave of innovation. As shown elsewhere in this Solutions Guide, the ability to seamlessly transition from 16GFC or Gen 6 Fibre Channel into NVMe-readiness offers operational risk mitigation to organizations that want to capitalize on their infrastructure investments while taking advantage of storage advances. If they wish to move forward to the fastest performance standards, all while preventing risk inherent in building parallel infrastructures and potentially increasing the TCO, Fibre Channel provides a well-tested and battle-hardened solution.

The NVMe over Fibre Channel standard is complete, making it the NVMe networking solution that is uniquely positioned among other emerging NVMe networking standards, with a clear path to the future.

Current Fibre Channel customers benefit from the investment protection in their SAN infrastructure that can outlast the current generation of flash storage array investments. New customers will benefit from having a well-understood transport technology to underlie a new technology (NVMe), thus minimizing the risks inherent in "moving parts."

With the Fibre Channel industry's 20 years of hindsight and experience, organizations can now benefit from the foresight of future NVMe with the preparedness of what's to come.

*Footnotes*

1. The Future of Storage Protocols, April 2017, Gartner Research
2. Tech Target Research, Storage Market Landscape Study, 1H 2017

# A Look at Fibre Channel's Legacy – And Future

*J Metz, Cisco Systems*

**Ah, storage.**

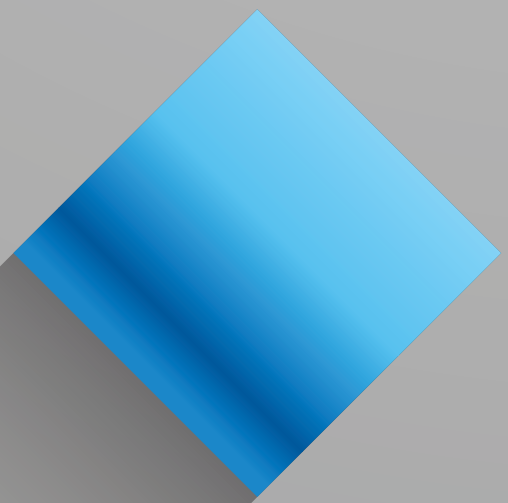
The most important part of any Data Center. Wait, wait, I get it – there are no *unimportant* parts of the Data Center. The ability to store and retrieve data, however, is the heart and soul, and the unmitigated catastrophe that befalls the company that loses data is impossible to overstate.

If you think about all the systems that are put in place to protect data – the generation, transmission, retention and retrieval (collectively known under the umbrella, "Storage") – the bulk of the energy spent is devoted to one basic, fundamental task: give me back the bit I asked you to hold on to.

This is not new – in fact, the ability to manage Storage has been a fundamental part of every computing system ever devised. The only questions have been, 1) how good is my ability to store and retrieve the data, 2) how much can I store, and 3) how fast can I do so?

## Building a Strong, Reliable, Dependable Network. For Storage.

Fibre Channel was not the first storage protocol solution – not by a long shot – but it did change the nature of how Data Centers worked. It could be argued that Fibre Channel was the first widely-adopted open standard interface that merged the performance and reliability of local storage with the connectivity and distance of networks.



Originally, and for several years afterwards, one of the main strengths of Fibre Channel was its raw power. At a time when I/O interfaces were capable of 20 MB/s (such as SCSI or ESCON), Fibre Channel rocked everyone's world with 100 MB/s. While others worked in half-duplex mode (limiting data to being moved in one direction at a time), Fibre Channel was full-duplex. While others were limited to only a few meters (SCSI was limited to under 7m, and only 7 devices), Fibre Channel allowed thousands of devices to be connected over distances of kilometers.

The significance of this can't be understated enough – we would not even be thinking of massively scalable storage networks had it not been for the pioneering efforts of the men and women who recognized that "status quo" is not "good enough." Without Fibre Channel, it's hard to imagine that there would have been a desire to push for massively scalable networks and global access to storage with any kind of reliability. Yet here we are.

Over time, an interesting thing happened. Fibre Channel became known less for its speed advantages (though this was obviously a major draw for the first decade-and-a-half), and more for its reliability. People came to count on the technology because, well, you could count on the technology.

You knew, for instance, that the 5,000th device you added to the fabric was going to behave just like the first. You knew that it was going to be just as easy to setup, just as fast, just as reliable. You knew that you could buy Fibre Channel equipment and that it would be fully qualified, tested, and hardened. You knew that the cards you bought for your servers were going to work with the arrays that you bought, because the vendors had spent Billions of dollars (yes, with a capital "B") to make it so. You knew that you could set this up and it would last for years.

The legacy of Fibre Channel, then, was not that it was so much faster than other technologies. (Admit it – did you remember exactly the difference between SCSI and Fibre Channel throughput in 1997?)

No, the true legacy of Fibre Channel is that in a world of disposable, commodity, unreliable components,

there is still a technology that you can depend upon for storage, because it was built for storage, and that mission has never changed. Ever.

## Looking to the Future

It seems that nowadays the trends of Data Center architectures are expanding and collapsing over time, much like an accordion. Depending upon who you ask, the pressure can be on increasing performance (which can limit scale), increasing scale (which can sacrifice performance), or manageability (which can sacrifice both performance and scale). Fibre Channel has solved – and continues to improve upon – each of these aspects of Data Center storage, and provides the underlying consistency that many people desire when adopting a new technology.

Throughout this Solutions Guide you've seen advances in speed, advances in topologies, and of course, advances in upper-layer protocols such as NVMe. Many people believe that NVMe is not just a new storage protocol – it means a fundamental, exponential shift in the capabilities and burdens inside of the Data Center. While this is exciting, and the possibilities for the future seem wide open once more, it is also scary for some – our job is still to securely and confidently store, transmit, and retrieve data without loss.

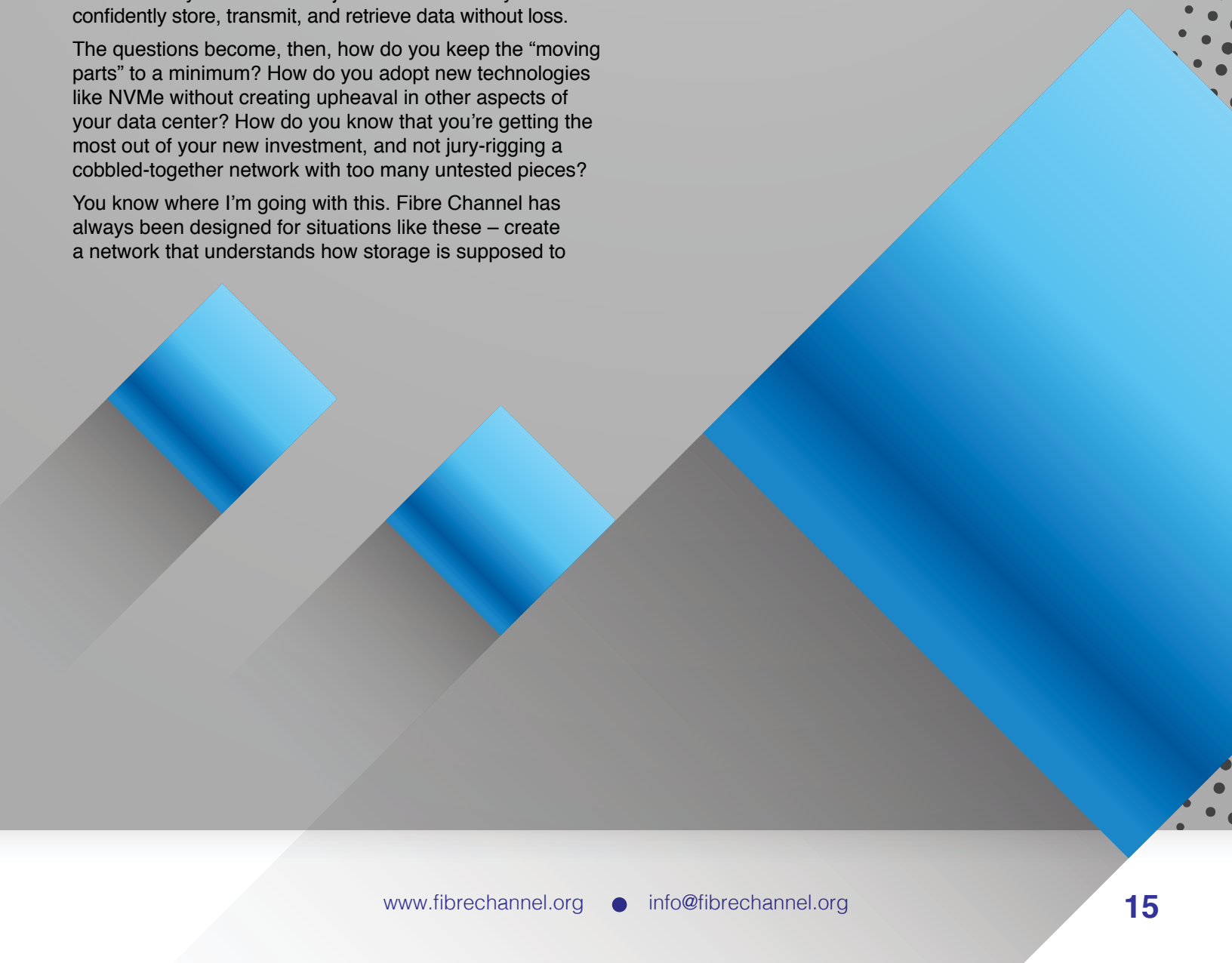
The questions become, then, how do you keep the "moving parts" to a minimum? How do you adopt new technologies like NVMe without creating upheaval in other aspects of your data center? How do you know that you're getting the most out of your new investment, and not jury-rigging a cobbled-together network with too many untested pieces?

You know where I'm going with this. Fibre Channel has always been designed for situations like these – create a network that understands how storage is supposed to work, what the expectations are end-to-end, and know that the entire solution is qualified, from Operating System to storage media.

## The Ecosystem Approach

At the end of the day, we want to make sure that when we innovate, we aren't sacrificing what we already have. It's okay to be excited about the potential for new technologies, but any experienced administrator knows that no technology works in isolation – simply adding NVMe to your data center is not a "one and done" situation, just like adding Virtualization wasn't simply adding "another operating system" to your servers.

The impact and effect of these new technologies don't change the nature of the storage problem; you still need to have store, transmit, and retrieve your data in a reliable, consistent, and guaranteed manner. Fibre Channel has two decades of an impeccable track record for these responsibilities, and will continue to remain the ultimate benchmark for complete storage solutions.

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