Fibre Channel Outlook
2021 and Beyond

Live Webcast
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About the Presenters

Mark Jones
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FCIA Board of Directors

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Marvell,
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FC-NVMe-2 Working Group,
FCIA Board of Directors

Rupin Mohan
Director R&D, CTO [SAN]
HPE
FCIA Board of Directors

Casey Quillin
Founder and Principal Analyst
Quillin Research
About the Fibre Channel Industry Association (FCIA)

25+ Years
Promoting Fibre Channel Technology

Industry Leading
Member Companies

142M+ FC Ports
Shipped Since 2001
Key Tenets of Fibre Channel

• Purpose-built as network fabric for storage and standardized in 1994, Fibre Channel (FC) is a complete networking solution, defining both the physical network infrastructure and the data transport protocols. Features include:
  
  – **Lossless, congestion free systems**—A credit-based flow control system ensures delivery of data as fast as the destination buffer can receive, without dropping frames or losing data.
  
  – **Multiple upper-layer protocols**—Fibre Channel is transparent and autonomous to the protocol mapped over it, including SCSI, TCP/IP, ESCON, and NVMe.
  
  – **Multiple topologies**—Fibre Channel supports point-to-point (2 ports) and switched fabric (224 ports) topologies.
  
  – **Multiple speeds**—Products are available supporting 8GFC, 16GFC, and 32GFC today.
  
  – **Security**—Communication can be protected with access controls (port binding, zoning, and LUN masking), authentication, and encryption.
  
  – **Resiliency**—Fibre Channel supports end-to-end and device-to-device flow control, multi-pathing, routing, and other features that provide load balancing, the ability to scale, self-healing, and rolling upgrades.
Agenda

• Fibre Channel Industry Overview – Mark Jones
• Market Landscape – Casey Quillin
• Fibre Channel Roadmap – Craig Carlson
• Automation & Orchestration – Rupin Mohan
Fibre Channel Industry Overview

Mark Jones
Fibre Channel Timeline

- **1988**: Work begins on FC protocol
- **1994**: FCA and FCLC Formed
- **1997**: 1Gb FC
- **1999**: FCIA Formed
- **1999**: FCIA Formed
- **2001**: 2Gb FC
- **2005**: 4Gb FC
- **2008**: 8Gb FC
- **2009**: FCOE
- **2012**: 16GFC
- **2015**: Gen6 32GFC
- **2015**: Gen6 32GFC
- **Today**: Gen7 64GFC

Additional technologies:

- Arbitrated Loop
- Virtualization NPIV
- NVMe Fabrics Fibre Channel
- Converged Networks
- Fabric Services
- Today Gen7 64GFC
How the FC Industry Innovates

Fibre Channel Industry

Fibre Channel Industry Association (Marketing)

INCITS T11 Standards Organization (Technical)

Press/Analysts Collateral /Education

End-User Influence

Requirements

Needs

Tight Collaboration

FC Innovations

Storage Innovations

Standards/Profiles
In 2020 Fibre Channel is the Premier Storage Transport

- **FC is the most trusted transport for enterprise storage**
  - Nearly all datacenter class storage arrays sell with FC
- **FC is a premium offering**
  - Not the cheapest – you get what you pay for (Performance, Reliability, Data Safety)
  - Most tested and supported of storage transports
- **FC has a healthy ecosystem**
  - Strong T11 standards future development schedule – continuous innovation!
  - Strong participation from the leaders of datacenter technology
  - FCIA leadership for industry direction
- **FC has huge installed base of loyal customers**
  - Repeat customers over 25 years and seven generations of re-investment
  - 142M ports sold, 37M in use today!
NVMe® over Fibre Channel

- Strong Industry-wide development support
  - 2014 T11 began work on FC-NVMe
  - Industry milestones: Demos, Plugfests, first product shipments
  - 2020 FC-NVMe-2 complete

- 2020: FC - Leading Fully Supported NVMe-oF™ Transport Solution
  - FC-NVMe solutions shipping from all major FC component/array storage vendors
  - Support for all major operating systems
  - Significant application performance improvements over traditional SCSI

- Future of NVMe/FC
  - Continued performance improvements as OS’s refine NVMe-oF transport
  - Broadened vendor and OS adoption
  - NVMe/FC to be springboard for future FC technology advancements: Stay tuned!
## 64GFC Gen7 Gets Real in 2021

### 2016 32GFC vs 2021 64GFC

<table>
<thead>
<tr>
<th>Users: The Need for Higher Performance Data Access</th>
<th>Servers: The capacity to process and use the performance</th>
<th>Storage: The ability for arrays to fulfill data requests at higher data rates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2016 - 32GFC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• DB - Increase adoption of DB data warehousing</td>
<td>• PCIe gen 3 x8 = 2P 32G(6.6G)</td>
<td>• All Flash arrays gaining traction - capable of high performance in modest config sizes</td>
</tr>
<tr>
<td>• VM - Storage migration a new thing</td>
<td>• Memory BW/density increase 150%</td>
<td></td>
</tr>
<tr>
<td>• VM - VDI fairly new</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2021 – 64GFC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• WW Data grew by 4x</td>
<td>• PCIe gen 4 x8 = 2P 64G(13.2G)</td>
<td>• All Flash now commonplace</td>
</tr>
<tr>
<td>• DB Data Warehousing to double in 5 years</td>
<td>• Memory BW/density (1.6x more BW, 2.6x greater capacity)</td>
<td>• NVMe drives replacing SSDs</td>
</tr>
<tr>
<td>• DB – BI use exploding</td>
<td></td>
<td>• Cost of flash dropping</td>
</tr>
<tr>
<td>• DB – AI has increased DB Query exponentially</td>
<td></td>
<td>• Performance of Flash increasing</td>
</tr>
<tr>
<td>• DB – IT Governance means regional replication of data</td>
<td></td>
<td>• SCM growth in server/storage</td>
</tr>
</tbody>
</table>
64GFC Accelerates Application Performance

Oracle DB Data Warehousing Query time/FC Link Speed

Data Warehouse “HammerDB TPC-H” DSS Benchmark
Oracle 19c / All Flash Array

Oracle 19c Server
64GFC HBA
64GFC Switch
All Flash Array (16GFC)

TPUT (MB/s)
0 1000 2000 3000 4000 5000 6000 7000
1 76 151 226 301 376 451 526 601 676 751 826 901 976 1051 1126 1201 1276 1351 1426 1501 1576 1651 1726 1801 1876 1951 2026 2101 2176 2251 2326 2401 2476 2551 2626 2701 2776 2851 2926 3001 3076 3151 3226 3301 3376 3451 3526 3601

Query Execution Time in Seconds
The Need for Fibre Channel Education

• Changes in IT Education Trends:
  – Fewer specialists – more generalists
  – Survey results*: 62% of new IT positions are being filled by generalists
  – Seasoned FC storage/SAN specialists are entering retirement age

• FCIA Education Initiative
  – Bi-monthly BrightTALK Expert webinars: https://www.brighttalk.com/channel/14967/
  – FCIA YouTube Channel: https://www.youtube.com/channel/UCeSb0O94Ot-RfZSDg2ykRBA
  – YouTube Playlists: Basics, Fibre Channel Expert Courses, FC-NVMe
  – www.Fibrechannel.org/fcia-blog

*ESG storage trend survey 62% of new IT positions are being filled by generalists
Market Landscape

Casey Quillin
**FC SAN MARKET**

2Q20

Total SAN Market
+2% Y/Y

Adapter Revenue
+15% Y/Y

Switch Revenue
-2% Y/Y
FC SAN MARKET

2Q20

Port Shipments

Down low-single-digit Y/Y
Down low-double-digit Q/Q
FC SAN MARKET

2Q20

Port Shipments

Up low-single-digit Y/Y
Down mid-single-digit Q/Q
FC SAN MARKET

MARKET TRENDS

Flash Arrays

NVMe

FC for Mission Critical Storage

FC Switches - Revenue by Speed

- 16 Gbps Fibre Channel
- >32 Gbps Fibre Channel
Fibre Channel Roadmap

Craig Carlson
Roadmap at a glance

- **Fibre Channel Speed**
- **FC Speed in Development**
- **FC Future Speed**
- **FCoE Speed**
- **FCoE Speed in Development**
- **FCoE Possible Future Speed**

- **Quad Lanes in QSFP**
- **Serial Lane in SFP**

- 2TFC
- 1TFC
- 512GFC
- 256GFC
- 128GFC
- 64GFC
- 32GFC
- 16GFC
- 8GFC

- 2005
- 2010
- 2015
- 2020
- 2025
- 2030
- 2035
**Fibre channel speeds**

<table>
<thead>
<tr>
<th>Product Naming</th>
<th>Throughput (Mbytes/s)*</th>
<th>Line Rate (Gbaud)</th>
<th>T11 Specification Technically Complete (Year) †</th>
<th>Market Availability (Year) †</th>
</tr>
</thead>
<tbody>
<tr>
<td>8GFC</td>
<td>1,600</td>
<td>8.5 NRZ</td>
<td>2006</td>
<td>2008</td>
</tr>
<tr>
<td>32GFC</td>
<td>6,400</td>
<td>28.05 NRZ</td>
<td>2013</td>
<td>2016</td>
</tr>
<tr>
<td>64GFC</td>
<td>12,800</td>
<td>28.9 PAM-4</td>
<td>2017</td>
<td>2020</td>
</tr>
<tr>
<td>128GFC</td>
<td>24,850</td>
<td>56.1 PAM-4</td>
<td>2021</td>
<td>2024</td>
</tr>
<tr>
<td>256GFC</td>
<td>TBD</td>
<td>TBD</td>
<td>2025</td>
<td>Market Demand</td>
</tr>
<tr>
<td>512GFC</td>
<td>TBD</td>
<td>TBD</td>
<td>2029</td>
<td>Market Demand</td>
</tr>
<tr>
<td>1TFC</td>
<td>TBD</td>
<td>TBD</td>
<td>2033</td>
<td>Market Demand</td>
</tr>
</tbody>
</table>

*FC* used throughout all applications for Fibre Channel infrastructure and devices, including edge and ISL interconnects. Each speed maintains backward compatibility at least two previous generations (i.e., 32GFC backward compatible to 16GFC and 8GFC)

*These numbers are representative throughput values for the line rate and are payload dependent
† Dates: Future dates estimated
ISL Speeds

ISLs are usually multi-lane interconnects used for non-edge, core connections, and other high speed applications demanding maximum bandwidth. ISLs utilize high bit-rates to accommodate the funneling of edge connections. Some ISL solutions are vendor-proprietary.

*These numbers are representative throughput values for the line rate and are payload dependent

† Equivalent Line Rate: Rates listed are equivalent data rates for serial stream methodologies.

‡ Dates: Future dates estimated

§ FCoE standard completion date is the completion of the Ethernet standard

<table>
<thead>
<tr>
<th>Product Naming</th>
<th>Throughput (MBytes/s)*</th>
<th>Line Rate (Gbaud)*</th>
<th>Standard Technically Complete (Year)§</th>
<th>Market Availability (Year)‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>10GFC</td>
<td>2,400</td>
<td>10.52 NRZ</td>
<td>2003</td>
<td>2009</td>
</tr>
<tr>
<td>40GFCoE</td>
<td>9,600</td>
<td>4X10.3125 NRZ</td>
<td>2010</td>
<td>2013</td>
</tr>
<tr>
<td>100GFCoE</td>
<td>24,000</td>
<td>4X25.78125 NRZ</td>
<td>2010</td>
<td>2017</td>
</tr>
<tr>
<td>128GFC</td>
<td>25,600</td>
<td>4X28.05 NRZ</td>
<td>2014</td>
<td>2016</td>
</tr>
<tr>
<td>200GFCoE</td>
<td>48,000</td>
<td>4X26.5625 PAM-4</td>
<td>2018</td>
<td>2020</td>
</tr>
<tr>
<td>256GFC</td>
<td>51,200</td>
<td>4X28.9 PAM-4</td>
<td>2018</td>
<td>2020</td>
</tr>
<tr>
<td>400GFCoE</td>
<td>96,000</td>
<td>8X26.5625 PAM-4</td>
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<td>TBD</td>
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</table>
Fibre Channel over Ethernet tunnels FC through Ethernet. 10GFCoE was not available until after FC-BB-5, the FCoE protocol standard, was completed in 2007. For compatibility, all 10GFCoE FCFs and CNAs are expected to use SFP+ devices, allowing the use of all standard and non-standard optical technologies and additionally allowing the use of direct connect cables using the SFP+ electrical interface. FCoE ports otherwise follow Ethernet standards and compatibility guidelines.

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<th>IEEE Standard Complete (Year)‡</th>
<th>Market Availability (Year)‡</th>
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</thead>
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<tr>
<td>10GFCoE</td>
<td>2,400</td>
<td>10.3125 NRZ</td>
<td>2002</td>
<td>2008</td>
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<tr>
<td>25GFCoE</td>
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‡ Dates: Future dates estimated
The Roadmap

• Goal is to double every speed increase (every 3 to 4 years)
  – Now working on 128GFC
• Speed increases are always backwards compatible with at least the previous 2 speeds
• Goal remains 100m reach for multi-mode
• Goal to decrease Latency
• Add more value-ad features
  – Automation and orchestration
SAN Automation – Enabling Deployment & Managing SAN’s Simple

Cloud Orchestration Platforms

Fibre Channel SAN Automation

Python Libraries

REST API

Fabric Notifications, Peer Zoning, Target Driven Peer Zoning

Industry Tools

HPE Smart SAN
HPE Network Orchestrator

HPE OneView

Hitachi
Inspire the Next

ANSIBLE

FCIA
Fibre Channel Industry Association
# Fabric Notifications

<table>
<thead>
<tr>
<th>FPIN Type</th>
<th>What it does</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric Performance Impact Notification</td>
<td></td>
</tr>
<tr>
<td>Congestion Notification (FPIN-CN)</td>
<td>Notifies the port that is causing congestion that it is causing congestion.</td>
</tr>
<tr>
<td>Link Integrity (FPIN-LI)</td>
<td>Notifies the server port that the link it is connected to is ‘sick but not dead.’</td>
</tr>
<tr>
<td>Peer Notification (FPIN-PN)</td>
<td>When a FPIN-CN is sent to the server causing congestion, a Peer Notification is sent to all of the other ports in the zone.</td>
</tr>
<tr>
<td>Delivery Notification (FPIN-DN)</td>
<td>Delivery Notification - Best example is if a switch drops a frame due to egress hold time expiring (220ms).</td>
</tr>
</tbody>
</table>

**Signals**

Instead of using ELS, in Gen 7 ASICs providing congestion notifications at the hardware level. In essence, congestion signals look like rapid FPIN-CNs.

The details are in FC-FS-6 (Congestion Signal) and FC-LS-5 (EDC, RDF, and FPIN ELSs).
# Target Driven Peer Zoning

<table>
<thead>
<tr>
<th>Feature</th>
<th>What it does?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer Zoning</td>
<td>A Peer Zone is a Zone that allows a “Principal” member to communicate with “Peer” members, and does not allow Peer members to communicate among themselves. Peer Zone identifies a Principal member through the Peer Zone Attribute as defined in the FC-GS-x standard.</td>
</tr>
<tr>
<td>Target Driven Peer Zoning</td>
<td>When a target device defines/creates and manages Peer Zones using in-band FC-CT commands (shown in this table), then it is called Target Driven Peer Zoning (TDPZ). Peer Zones can be defined/created by other mechanisms as well.</td>
</tr>
</tbody>
</table>
| AAPZ | Add/Replace Active Peer Zone (AAPZ) Operation  
A Target that supports TDPZ sends this command (along with the right attributes) to the Fabric Zone Server (that resides in the attached switch) to create a new Peer Zone or update an existing Peer Zone with the same name. |
| RAPZ | Remove Active Peer Zone (RAPZ) Operation  
A Target that supports TDPZ sends this command to the Fabric Zone Server (that resides in the attached switch) to remove an existing Peer Zone that matches with the Zone Name specified in the command payload. |
| GAPZ | Get Active Peer Zone (GAPZ) Operation  
A Target that supports TDPZ sends this command to the Fabric Zone Server (that resides in the attached switch) to retrieve an existing Peer Zone. The Fabric Zone Server shall return the Peer Zone definition in the Active Zone Set having the specified Zone Name. |

Peer Zoning and details of AAPZ/RAPZ/GAPZ are described in FC-GS-x standard.
Fibre Channel 2020 Solutions Guide

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*https://fibrechannel.org/fibre-channel-solution-guide-2020/*
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• Please rate this event – we value your feedback
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  – Fibre Channel Fundamentals
  – FC-NVMe
  – Long Distance Fibre Channel
  – Fibre Channel Speedmap
  – FCIP (Extension): Data Protection and Business Continuity
  – Fibre Channel Performance
  – FICON
  – Fibre Channel Cabling
  – 64GFC
  – FC Zoning Basics
  – Fibre Channel Standards
Thank You