Protocol Analysis for High-Speed Fibre Channel Fabrics in the Data Center

Aka, Saving Your SAN (& Sanity)

Live Webcast
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FIBRE CHANNEL INDUSTRY ASSOCIATION

Today's Speakers

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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.”

About the FCIA

- The FCIA promotes the advancement of Fibre Channel technologies and products that conform to the existing and emerging T11 standards.
- The FCIA maintains resources and supports activities to ensure multi-vendor interoperability for hardware, interconnection, and protocol solutions.
- The FCIA activities include; promotion and marketing of FC solutions, educational awareness campaigns, hosting public interoperability demonstrations, and fostering technology and standards conformance.

Agenda

- **Basic Premise**
  - Universal Test Considerations/Expectations
  - Current Test Practices/Tools
- **Line Rate Analysis**
- **Protocol of the Phy**
- **Above the Phy**
- **Performance Metrics**
- **Debug Examples**
- **Traffic Impairment**
  - Applications for Jamming real-time Traffic

High-Speed Fabric Designs and Protocol Analysis

Basic Premise:
Market Drivers are fueling the exponential growth of Fibre Channel speeds, port counts and densities. The challenge to meet the demands of users and applications, and seamlessly interoperate across the fabric requires adaptation and evolution of test and measurement tools and practices.

The impact on hardware designs requires protocol awareness beginning with initial design, through validation, and in the field after deployment.

Universal T&M Considerations

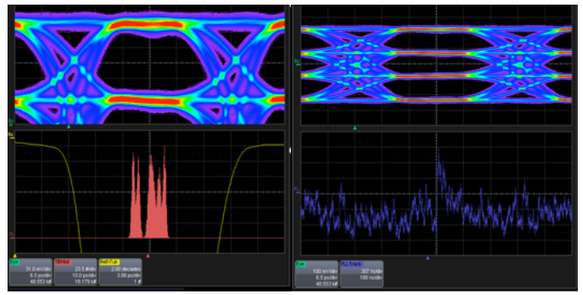
- **Common to all stages of Development, Deployment, and Support**
  - What issue(s) are we trying to understand and correct?
  - When and How does the issue manifest?
  - Is the issue reproducible?
  - Can root cause be definitively determined?
  - What are the curative measures?
  - Can you test the ‘fix’?

Universal T&M Expectations

- **Ubiquitous deployment requires vendor interoperability**
- **Mission Critical applications demand reliability and consistency**
  - Minor Imperfections no longer ‘accepted’ as normal and unremarkable
- **Integrating legacy and new Fibre Channel technologies creating new challenges**
- **Exponential Storage Growth and Content Delivery demands require 5-9s of up time.**
- **It’s imperative to know what’s “on the wire”**
  - Testing no longer “ends” at the connector/ASIC

Fibre Channel T&M Today

- **The "Old Way" of Hardware Testing**
  - Relies on Scopes, BERTs, PERTs, Traffic Generators
  - Accompanied by home grown applications



- **Tool limitations include the inability to readily decipher the Phy layer transactions to determine root cause in basic Phy Layer communications failures.**
  - Why didn't the link come up?
  - Both link participants advertise 32GFC capability, but will only link at 16GFC
  - Speed Negotiation completes, however transmitter training fails
  - How do you determine the link transitions indicated by the scope?

Test & Measurement Advancements

- **Updated and New Tools for the PHY**
- **High Speed Real Time and/or Sampling Scopes**
  - Up to 100GHz Today!
- **Specialized Traffic Generation and Analysis Capabilities Supporting**:
  - Physical Coding Sublayer – 8b/10b, 64b/66b, encoding (and beyond…256b/257b)
  - Speed-Negotiation, Transmitter Training Sequences
- **Line Rate analysis capabilities:**
  - "Pass Through" tapping
  - Bit-level Capture
  - Traffic Impairment (aka Jamming)
- **The "Road" must be "smart"**
  - Protocol is inherent in the physical layer!

Start Time	Port	Speed	Destination Addr.	Source Addr.	Protocol	Frame	Frame
01.27 456 565 527(min)	P2	16G			FC		114 - LR
01.27 456 565 534(min)	P1	16G			FC	112 - LR	
01.27 456 565 794(min)	P2	16G			FC		113 - LRR
01.27 456 565 797(min)	P1	16G			FC	115 - LRR	

Index	Data			
0001	BC	49	BF	49

Field	Value
Ordered Set	0xBC49BF49 : LR
Control Code	0xBC
Modifier 1	0x49
Modifier 2	0xBF
Modifier 3	0x49

Index	Data			
0001	BC	35	BF	49

Field	Value
Ordered Set	0xBC35BF49 : LRR
Control Code	0xBC
Modifier 1	0x35
Modifier 2	0xBF
Modifier 3	0x49

Test Tools – Application Areas

Test Tools →	JTAG/ ASIC	FMU/ VDs	HW Analyzer	DPI Tools	Scope	Generator/ IO tools	Jammer
Hardware Test	✓	X	✓	X	✓	✓	✓
Validation Labs	✓	✓	✓	✓	✓	✓	✓
Simulation Labs	✓	✓	✓	✓	X	✓	✓
Support Teams	X	✓	✓	✓	X	✓	✓
Data Centers	X	✓	X	✓	X	X	✓

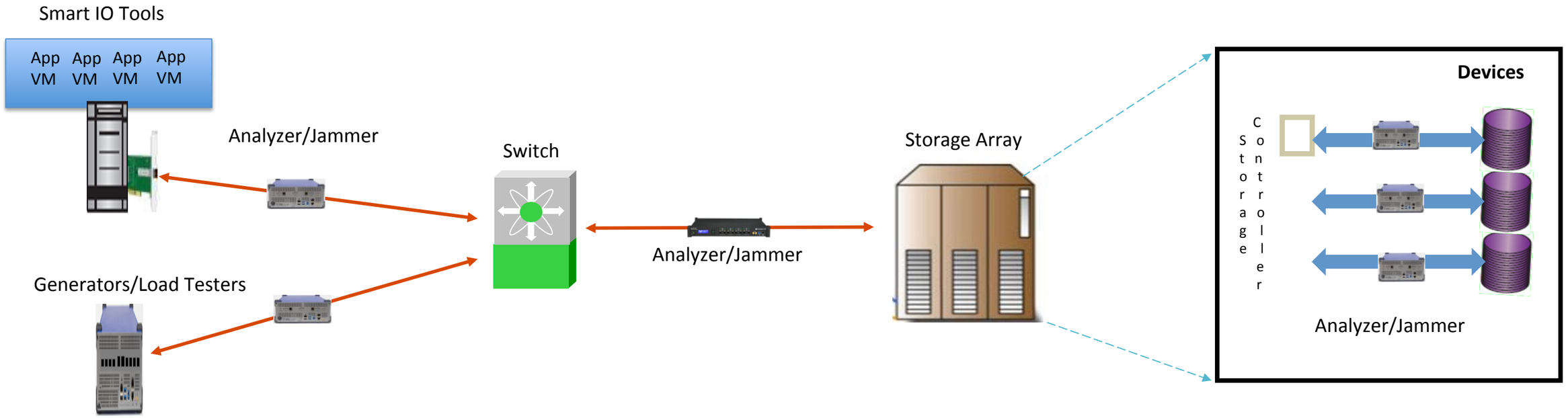
✓ Primary tool in that test space

✓ Secondary tool in that test space

X Not used in that test space

FMU – Fabric management utility
VD – Vendor-specific diagnostic tool

Device and Interop Testing

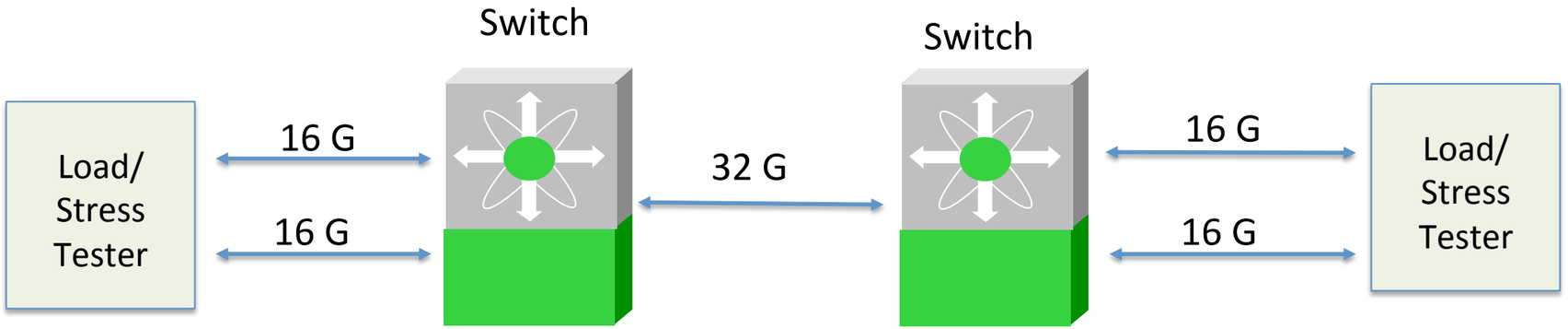


Generators/IO Tools
- Performance Testing
- Compliance Testing
- Functionality Testing
- Data Integrity Testing

Analyzer
- Capture and Analysis
- Protocol Violations/Errors
- Interop Testing

Jammer
- Error Injection
- Error Recovery

Stress Testing



Load Testers/BERTs

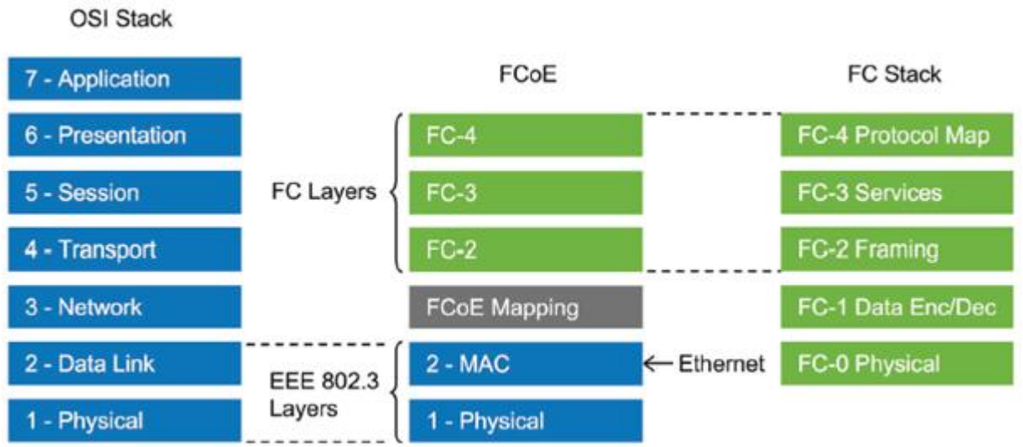
- Scalability Testing
- Stress Testing
  - High throughput
  - Check for dropped frames
  - Test latency under various load conditions
  - Error recovery

Different combination of these tools is used for overall testing and analysis

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.



*Reprinted from Fibre Channel Interoperability Webcast, https://fibrechannel.org/webcasts/

FC Layers

FC Issues at the layers

Layer	Function	Issues
FC-4	Upper Layer protocol mapping	Latency Issues?
FC-3	Common Services	Advertise Functionality?
FC-2	Framing/Flow Control	B2B Credit issues?
FC- 1	Encode/Decode	Speed Negotiation, Transmitter Training?
FC-0	Phy Layer	Cable, TX/RX issues

- **FC-0: The physical media interface**
  - Transceivers, cables, etc.
- **FC-1: Transmission protocol or data-link layer**
  - Encodes and decodes signals
- **FC-2: Framing/Signaling**
  - Class of Service and Flow Control Protocol.
- **FC-3: Common services layer**
  - Advanced features like striping, encryption, multiport connections. And Extended Link Services.
- **FC-4: Protocol-mapping layer**
  - NVMe, SCSI, IP or FICON.

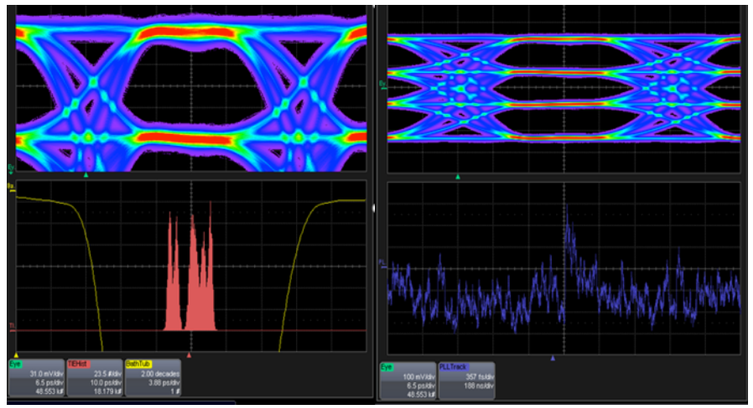
FC-0 and FC-1

- **FC-0: The physical media interface**
  - Transceivers, cables, etc.
- **FC-1: Transmission protocol or data-link layer**
  - Encodes and decodes signals
- FC-2: Framing/Signaling
  - Class of Service and Flow Control Protocol.
- FC-3: Common services layer
  - Extended Link Services, striping, encryption, multiport connections.
- FC-4: Protocol-mapping layer
  - NVMe, SCSI, IP or FICON.

Layer	Function	Issues
FC- 1	Encode/Decode	Speed Negotiation, Transmitter Training?
FC-0	Phy Layer	Cable, TX/RX issues

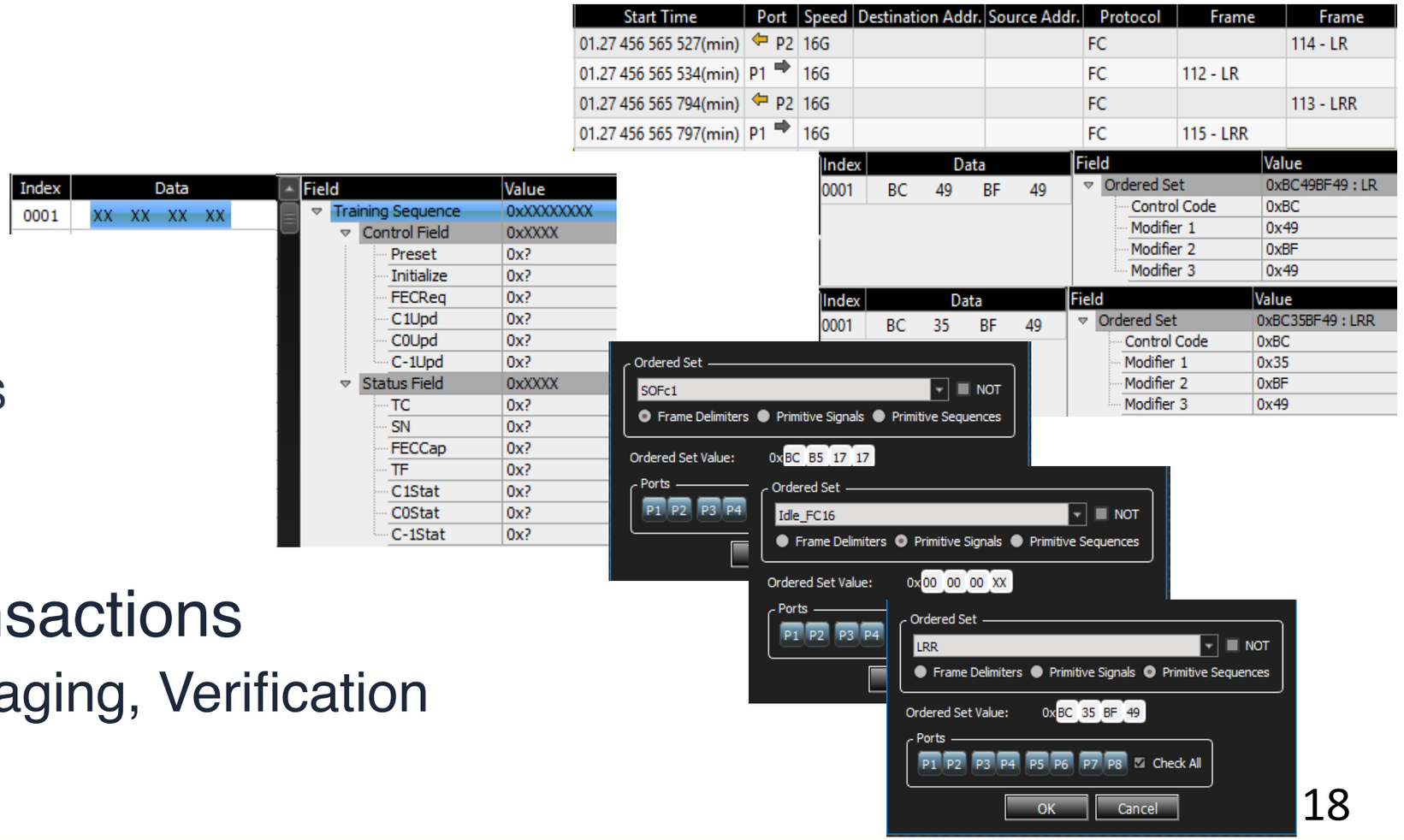
FC-0, Physical Layer

- **Designs Considerations to Support both for Legacy and New links**
- **The Tool Sets Must be Capable of Adapting to the "protocol" of the Phy**
  - Speed-negotiation
  - Transmitter Training
  - FEC
- **No two vendors implementations are identical**
  - Even when using similar components
- ✓ **T11 Specification Adherence**
- ***Interoperability is Mandatory For New and Legacy environments!***



FC-1, Link Layer

- **Supports the Specifics for Link Control including;**
  - Ordered Sets
    - Frame Delimiters
      - SOF, EOF
    - Primitive Signaling
      - Idles, R_RDY, ARB
    - Primitive Sequences
      - LR, LRR, NOS, OLS
  - Encoding/Decoding
  - Transmitter Training
- Characterize the transactions
  - Timing, Control Messaging, Verification



FC-2

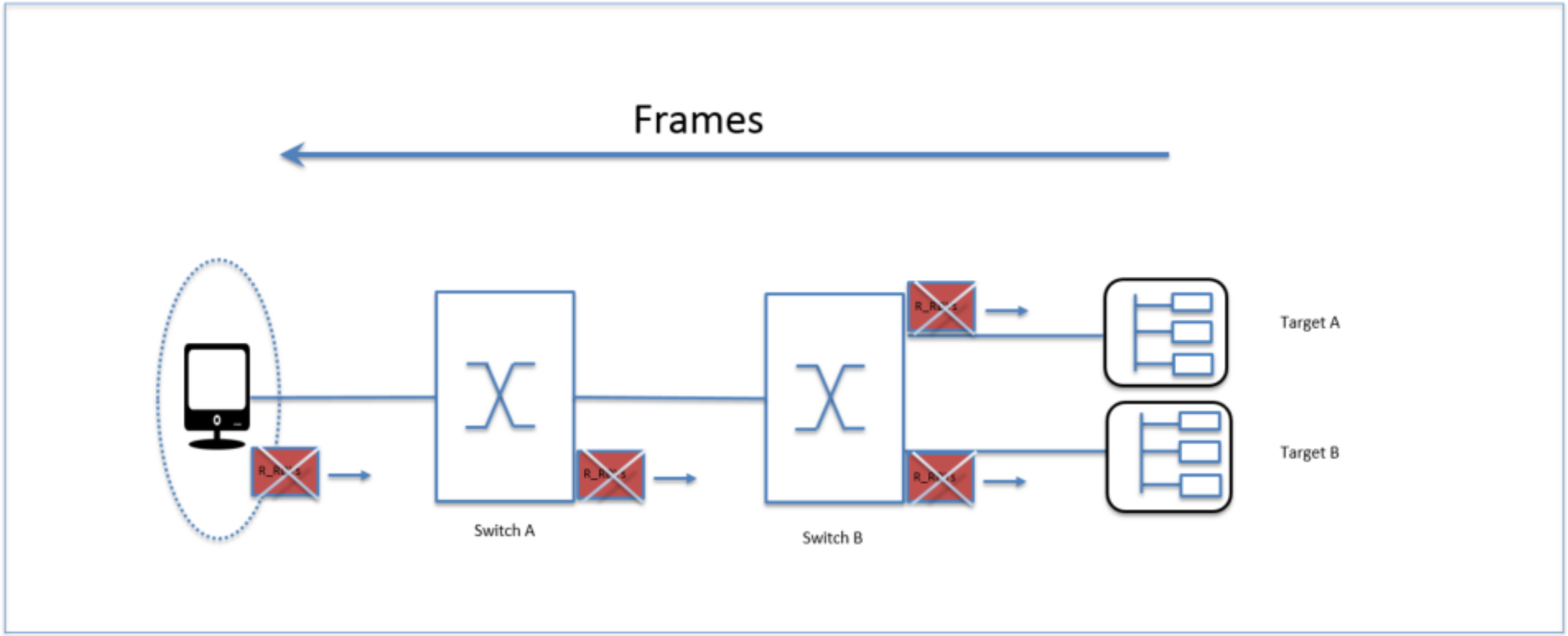
- FC-0: The physical media interface
  - Transceivers, cables, etc.
- FC-1: Transmission protocol or data-link layer
  - Encodes and decodes signals
- **FC-2: Framing/Signaling**
  - Class of Service and Flow Control Protocol.
- FC-3: Common services layer
  - Extended Link Services, striping, encryption, multiport connections.
- FC-4: Protocol-mapping layer
  - NVMe, SCSI, IP or FICON.

Layer	Function	Issues
FC-2	Framing/Flow Control	B2B Credit issues?

FC-2, Framing Layer

- **Defines Framing, Class of Service, Flow Control**
- **Assert appropriate CoS**
  - Fabric partners advertising the same CoS
- **B2B Credits**
  - Exchange of B2B credits
  - Crucial to successful FC communications between switches/devices

FC- 2, Flow Control Protocol



Slow Drain – Can be caused by Bad device behavior/Lost credits

FC-2, Congestion

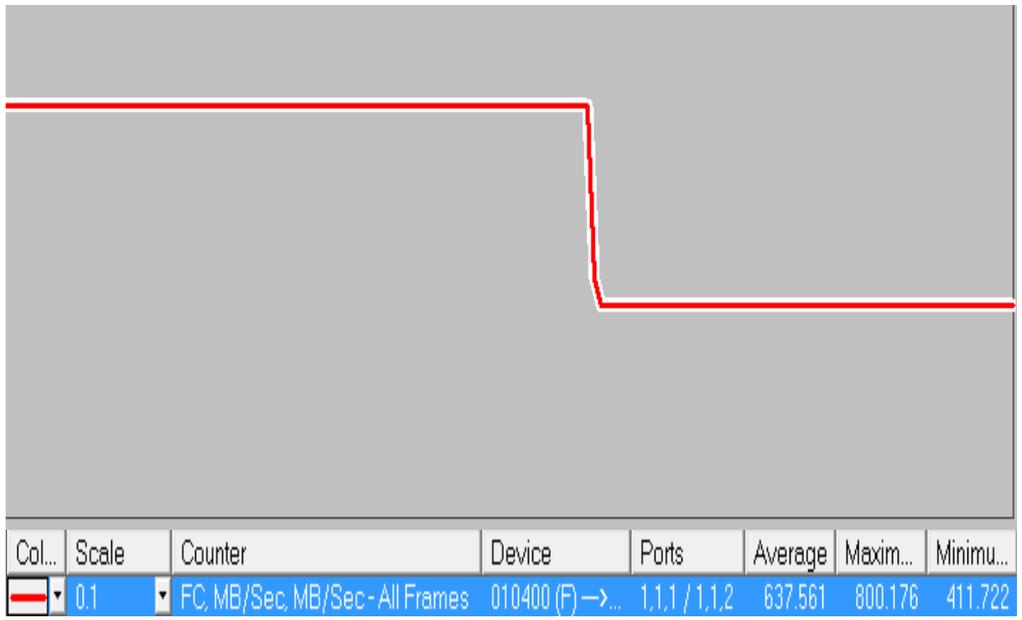
Monitor:

- 0 credit situations vs Frame counts
- Time in 0 credit situations
- Frame to R_RDY times - both direction
- Set default thresholds

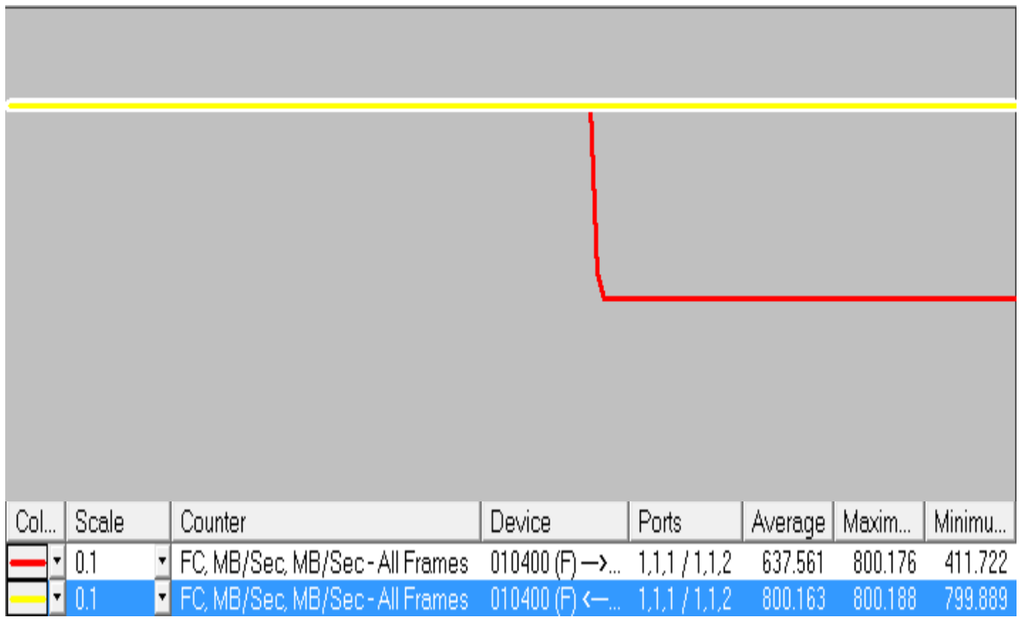
Effects:

- Performance Dips/Link Timeouts/Application Failures

Debug Example – Credit Delay



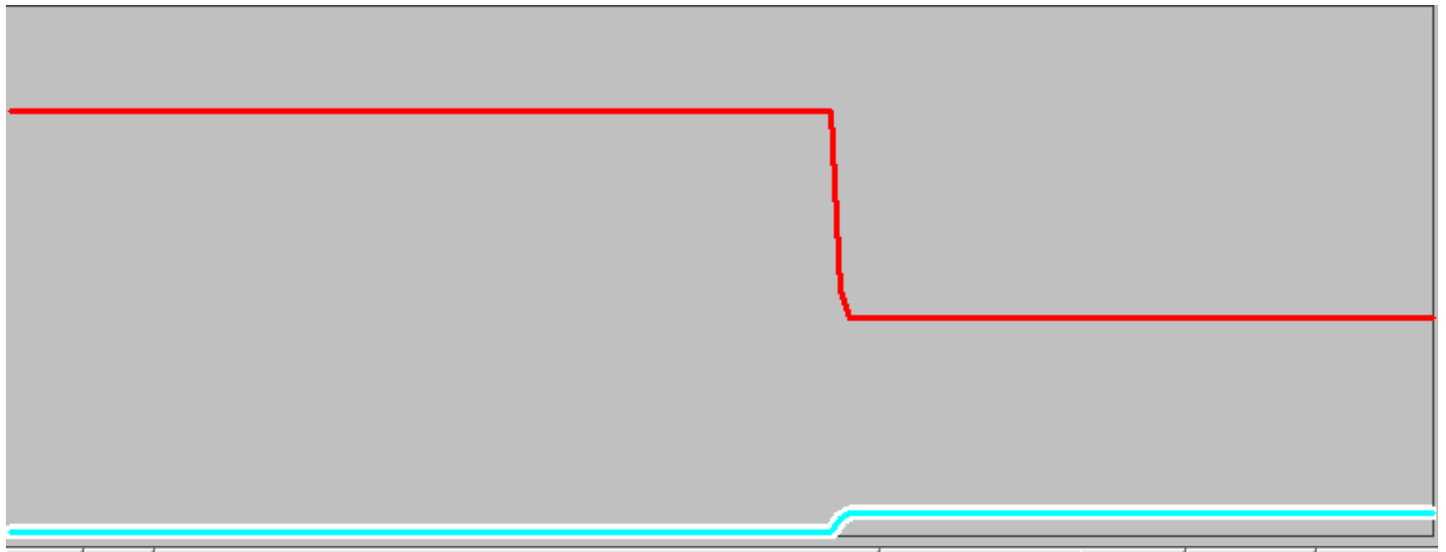
Graph 1: Plot MB/Sec in → direction



Graph 2: Plot MB/Sec in ← directions

The performance dip shown in → Direction

Debug Example – Credit Delay



Col...	Sc...	Counter	Device	Avera...	Maximum	Minimum
	1.0	FC, Credits - Switched Fabric, Frame to R_Rdy Time (Avg. - us)	F_Port —>	2.098	4.186	0.595
	0.1	FC, MB/Sec, MB/Sec - All Frames	010400 (F) —>	637.561	800.176	411.722

Graph 3: Plot Frame to R_RDY Time in → direction

Conclusion: The performance dip was caused by the delay in replenishing R_RDYs.

FC-3

- FC-0: The physical media interface
  - Transceivers, cables, etc.
- FC-1: Transmission protocol or data-link layer
  - Encodes and decodes signals
- FC-2: Framing/Signaling
  - Class of Service and Flow Control Protocol.
- **FC-3: Common services layer**
  - Extended Link Services, striping, encryption, multiport connections.
- FC-4: Protocol-mapping layer
  - NVMe, SCSI, IP or FICON.

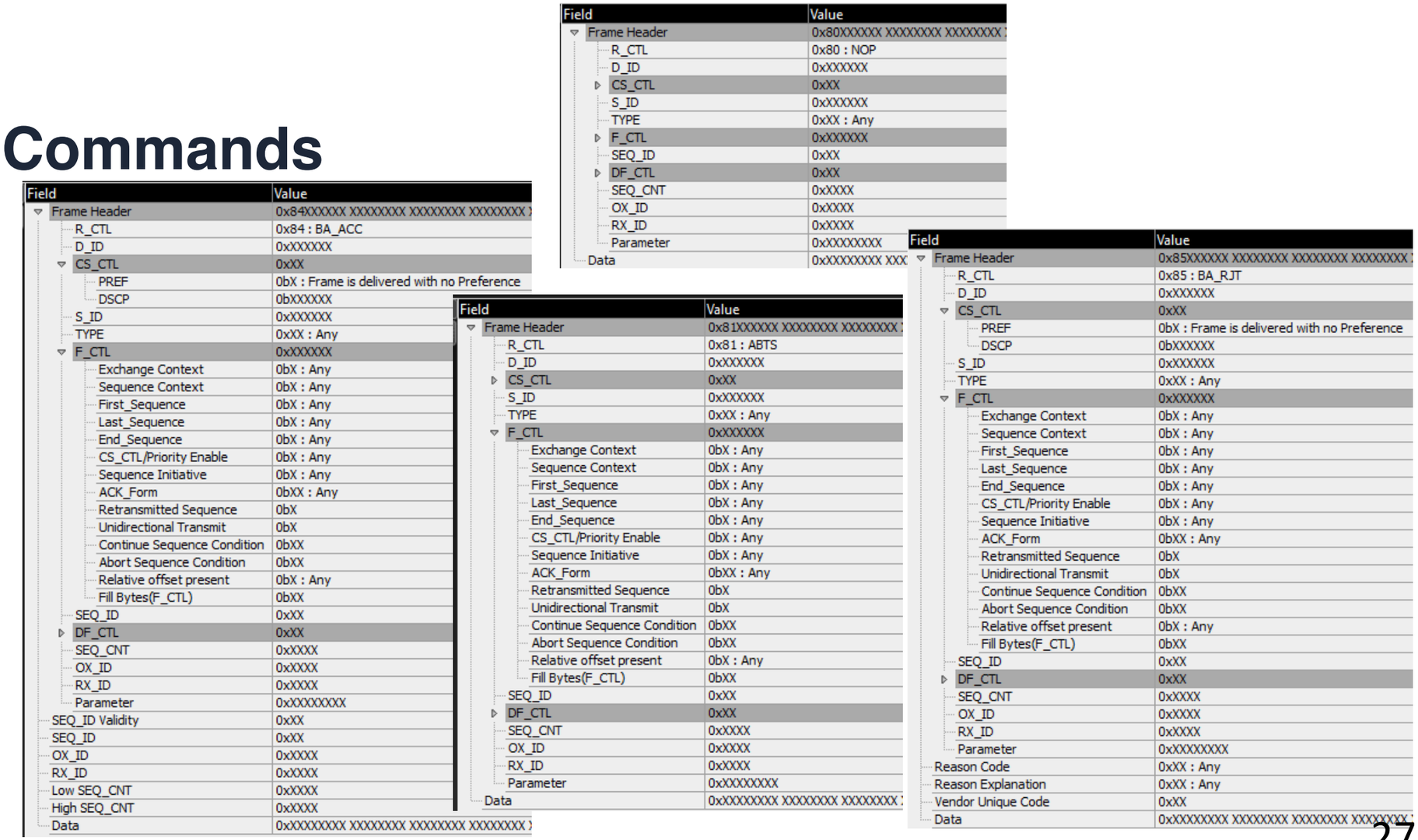
Layer	Function	Issues
FC-3	Common Services	Advertise Functionality?

FC-3, Link Services

- **The “Dispatcher” For FC Communications!**
- **Basic Link Services**
  - Link Services
  - Link Controls
    - Preference
    - Confirm OX_ID and RX_ID values
- **Extended Link Services, ELS**

Basic Link Services

- **Common LS Commands**
  - ABTS
  - NOP
  - BA_ACC
  - BA_RJT



Field	Value
Frame Header	0x84XXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
R_CTL	0x84 : BA_ACC
D_ID	0xXXXXXX
CS_CTL	0xXX
PREF	0bX : Frame is delivered with no Preference
DSCP	0bXXXXXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
Exchange Context	0bX : Any
Sequence Context	0bX : Any
First_Sequence	0bX : Any
Last_Sequence	0bX : Any
End_Sequence	0bX : Any
CS_CTL/Priority Enable	0bX : Any
Sequence Initiative	0bX : Any
ACK_Form	0bXX : Any
Retransmitted Sequence	0bX
Unidirectional Transmit	0bX
Continue Sequence Condition	0bXX
Abort Sequence Condition	0bXX
Relative offset present	0bX : Any
Fill Bytes(F_CTL)	0bXX
SEQ_ID	0xXX
DF_CTL	0xXX
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
SEQ_ID Validity	0xXX
SEQ_ID	0xXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Low SEQ_CNT	0xXXXX
High SEQ_CNT	0xXXXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX

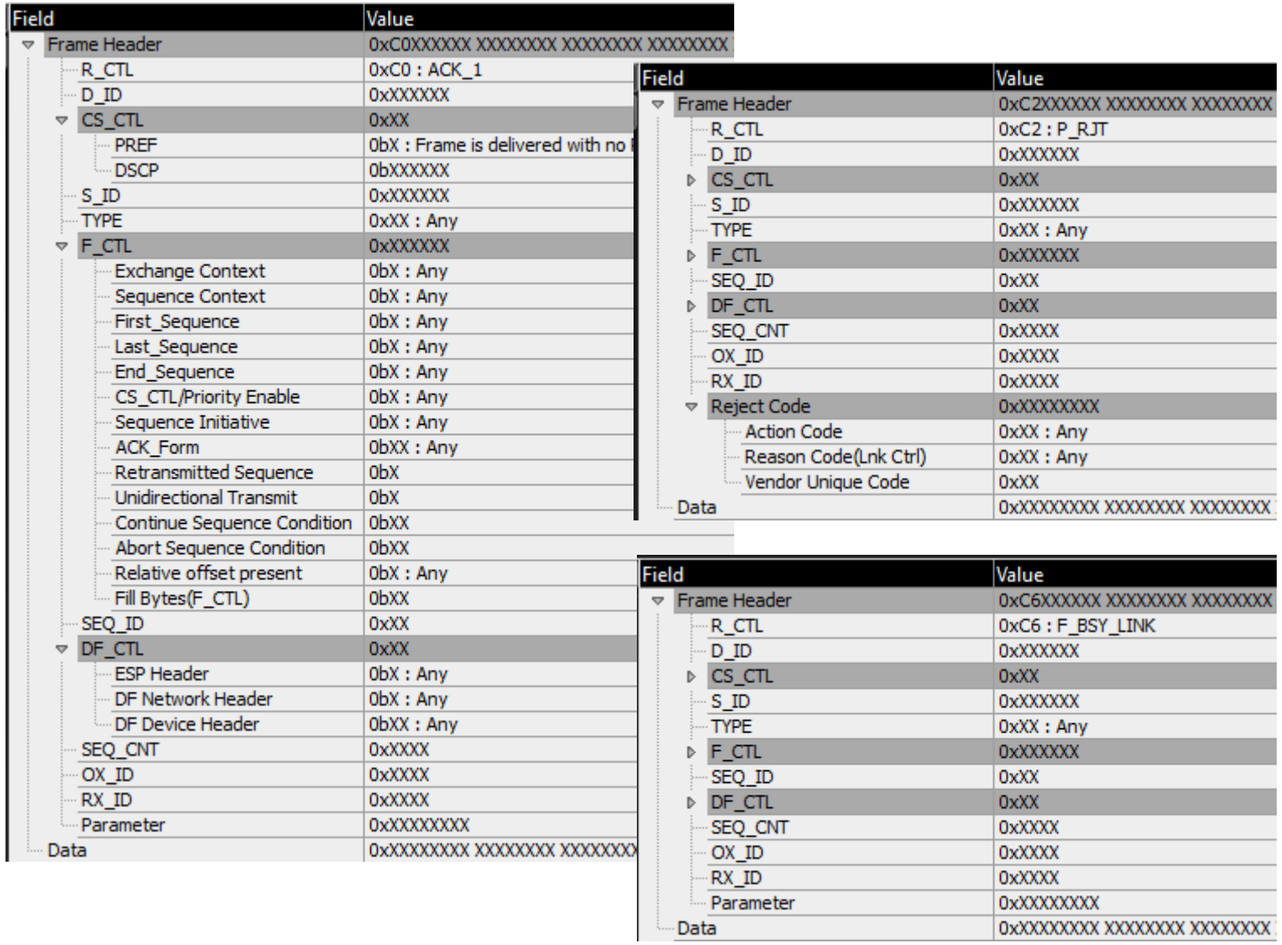
Field	Value
Frame Header	0x80XXXXXX XXXXXXXX XXXXXXXX
R_CTL	0x80 : NOP
D_ID	0xXXXXXX
CS_CTL	0xXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
SEQ_ID	0xXX
DF_CTL	0xXX
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
Data	0xXXXXXXXX XXX

Field	Value
Frame Header	0x81XXXXXX XXXXXXXX XXXXXXXX
R_CTL	0x81 : ABTS
D_ID	0xXXXXXX
CS_CTL	0xXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
Exchange Context	0bX : Any
Sequence Context	0bX : Any
First_Sequence	0bX : Any
Last_Sequence	0bX : Any
End_Sequence	0bX : Any
CS_CTL/Priority Enable	0bX : Any
Sequence Initiative	0bX : Any
ACK_Form	0bXX : Any
Retransmitted Sequence	0bX
Unidirectional Transmit	0bX
Continue Sequence Condition	0bXX
Abort Sequence Condition	0bXX
Relative offset present	0bX : Any
Fill Bytes(F_CTL)	0bXX
SEQ_ID	0xXX
DF_CTL	0xXX
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX

Field	Value
Frame Header	0x85XXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
R_CTL	0x85 : BA_RJT
D_ID	0xXXXXXX
CS_CTL	0xXX
PREF	0bX : Frame is delivered with no Preference
DSCP	0bXXXXXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
Exchange Context	0bX : Any
Sequence Context	0bX : Any
First_Sequence	0bX : Any
Last_Sequence	0bX : Any
End_Sequence	0bX : Any
CS_CTL/Priority Enable	0bX : Any
Sequence Initiative	0bX : Any
ACK_Form	0bXX : Any
Retransmitted Sequence	0bX
Unidirectional Transmit	0bX
Continue Sequence Condition	0bXX
Abort Sequence Condition	0bXX
Relative offset present	0bX : Any
Fill Bytes(F_CTL)	0bXX
SEQ_ID	0xXX
DF_CTL	0xXX
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
Reason Code	0xXX : Any
Reason Explanation	0xXX : Any
Vendor Unique Code	0xXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX

Link Controls

- **Common LC Commands**
  - ACK
  - F_BSY
  - F_RJT
  - P_BSY
  - P_RJT



Field	Value
Frame Header	0xC0XXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
R_CTL	0xC0 : ACK_1
D_ID	0xXXXXXX
CS_CTL	0xXX
PREF	0bX : Frame is delivered with no
DSCP	0bXXXXXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
Exchange Context	0bX : Any
Sequence Context	0bX : Any
First_Sequence	0bX : Any
Last_Sequence	0bX : Any
End_Sequence	0bX : Any
CS_CTL/Priority Enable	0bX : Any
Sequence Initiative	0bX : Any
ACK_Form	0bXX : Any
Retransmitted Sequence	0bX
Unidirectional Transmit	0bX
Continue Sequence Condition	0bXX
Abort Sequence Condition	0bXX
Relative offset present	0bX : Any
Fill Bytes(F_CTL)	0bXX
SEQ_ID	0xXX
DF_CTL	0xXX
ESP Header	0bX : Any
DF Network Header	0bX : Any
DF Device Header	0bXX : Any
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX

Field	Value
Frame Header	0xC2XXXXXX XXXXXXXX XXXXXXXX
R_CTL	0xC2 : P_RJT
D_ID	0xXXXXXX
CS_CTL	0xXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
SEQ_ID	0xXX
DF_CTL	0xXX
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Reject Code	0xXXXXXXXX
Action Code	0xXX : Any
Reason Code(Lnk Ctrl)	0xXX : Any
Vendor Unique Code	0xXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX

Field	Value
Frame Header	0xC6XXXXXX XXXXXXXX XXXXXXXX
R_CTL	0xC6 : F_BSY_LINK
D_ID	0xXXXXXX
CS_CTL	0xXX
S_ID	0xXXXXXX
TYPE	0xXX : Any
F_CTL	0xXXXXXX
SEQ_ID	0xXX
DF_CTL	0xXX
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX

Extended Link Services

- **Common ELS Commands and Response**
  - PLOGI
  - FLOGI
  - PRLI
  - PRLO
  - LS_ACC
  - LS_RJT

Field	Value
ELS Command	0x03 : PLOGI
Common Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Buffer-to-Buffer Credit	0xXXXX
Common Features	0xXXXX
BB_SC_N	0xX
Buffer-to-Buffer Receive Data...	0xXXX
Nx_Port Total Concurrent Seq...	0xXX
Relative Offset By Info Categ...	0xXXXX
E_D_TOV Value	0xXXXXXXXX
Port_Name	0xXXXXXXXX XXXXXXXX
Node_ Or Fabric_Name	0xXXXXXXXX XXXXXXXX
Class 1 Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Class 2 Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Class 3 Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Service Options	0xXXXX
Class Validity	0bX : Any
Priority/Preemption	0bX : Any
Preference	0bX : Any
DiffServ QoS	0bX : Any
Initiator Control	0bXXXXXXXX XXXXXXXX
Initial Responder Process_...	0x? : Any
Clock Synchronization ELS ...	0bX : Any
Recipient Control	0xXXXX
E_D_TOV Resolution	0bXX : Any
Categories Per Sequence	0bXX : Any
Clock Synchronization ELS ...	0bX : Any
Receive Data_Field Size	0xXXX
Concurrent Sequences	0xXX
Open Sequences Per Exchange	0xXX
Vendor Version Level	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX

Field	Value
ELS Command	0x20 : PRLI
Page Len.	0xXX
Payload Len.	0xXXXX
Service Parameter Page	0xXXXXXXXX XXXXXXXX
Type Code Or Common Servic...	0xXX : Any
Type Code Extension	0xXX
Originator Process_Associator ...	0bX
Responder Process_Associato...	0bX
Establish Image Pair	0bX
Originator Process_Associator	0xXXXXXXXX
Responder Process_Associator	0xXXXXXXXX
Service Parameters	0xXXXXXXXX XXXXXXXX

Field	Value
ELS Command	0x04 : FLOGI
Common Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Buffer-to-Buffer Credit	0xXXXX
Common Features	0xXXXX
Multiple N_Port_ID Support	0bX : Any
Virtual Fabrics Bit	0bX : Any
Valid Vendor Version Level	0bX : Any
N_Port/F_Port	0bX : Any
BB_Credit Management	0bX : Any
Name Server Session Begin	0bX
Energy Efficient LPI Mode ...	0x?
Priority Tagging Supported	0x?
Query Data Buffer Conditi...	0bX : Any
Security Bit	0bX : Any
Clock Synchronization Prim...	0bX : Any
R_T_TOV Value	0bX : Any
Dynamic Half Duplex Supp...	0bX : Any
Valid Vendor Version Level	0bX : Any
Payload Bit	0bX : Any
BB_SC_N	0xX
Buffer-to-Buffer Receive Data...	0xXXX
Port_Name	0xXXXXXXXX XXXXXXXX
Node_ Or Fabric_Name	0xXXXXXXXX XXXXXXXX
Class 1 Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Class 2 Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Class 3 Service Parameters	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
Service Options	0xXXXX
Class Validity	0bX : Any
Sequential Delivery	0bX : Any
Priority/Preemption	0bX : Any
Preference	0bX : Any
DiffServ QoS	0bX : Any
Initiator Control	0bXXXXXXXX XXXXXXXX
Clock Synchronization ELS ...	0bX : Any
Recipient Control	0xXXXX
Clock Synchronization ELS ...	0bX : Any
Vendor Version Level	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX

Field	Value
ELS Command	0x21 : PRLO
Payload Len.	0xXXXX
Logout Parameter Page	0xXXXXXXXX XXXXXXXX
Type Code Or Common Logout...	0xXX
Type Code Extension	0xXX
Originator Process_Associator ...	0bX
Responder Process_Associato...	0bX
Originator Process_Associator	0xXXXXXXXX
Responder Process_Associator	0xXXXXXXXX
Logout Service Parameters	0xXXXXXXXX

FC-4

- FC-0: The physical media interface
  - Transceivers, cables, etc.
- FC-1: Transmission protocol or data-link layer
  - Encodes and decodes signals
- FC-2: Framing/Signaling
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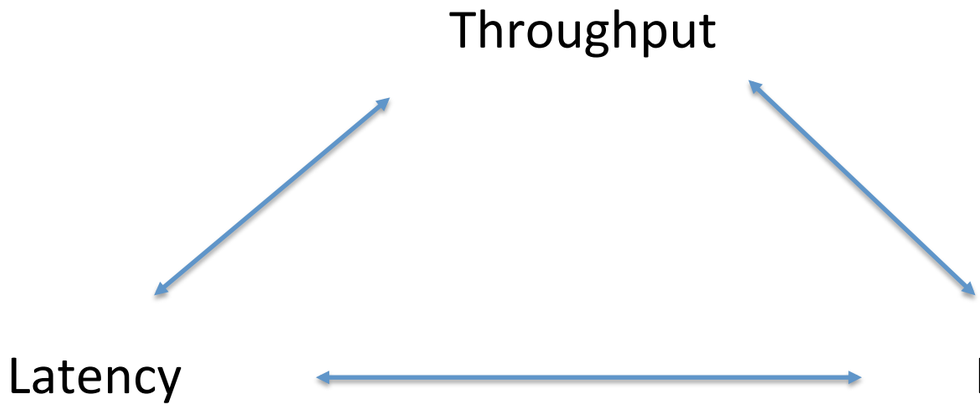
- FC-3: Common services layer
  - Extended Link Services, striping, encryption, multiport connections.
- **FC-4: Protocol-mapping layer**
  - NVMe, SCSI, IP or FICON.

Layer	Function	Issues
FC-4	Upper Layer protocol mapping	Latency Issues?

FC-4, Performance Metrics



- IO Size
- IO Direction
- IO Pattern
- Bandwidth Available

Throughput = IOPS x I/O size

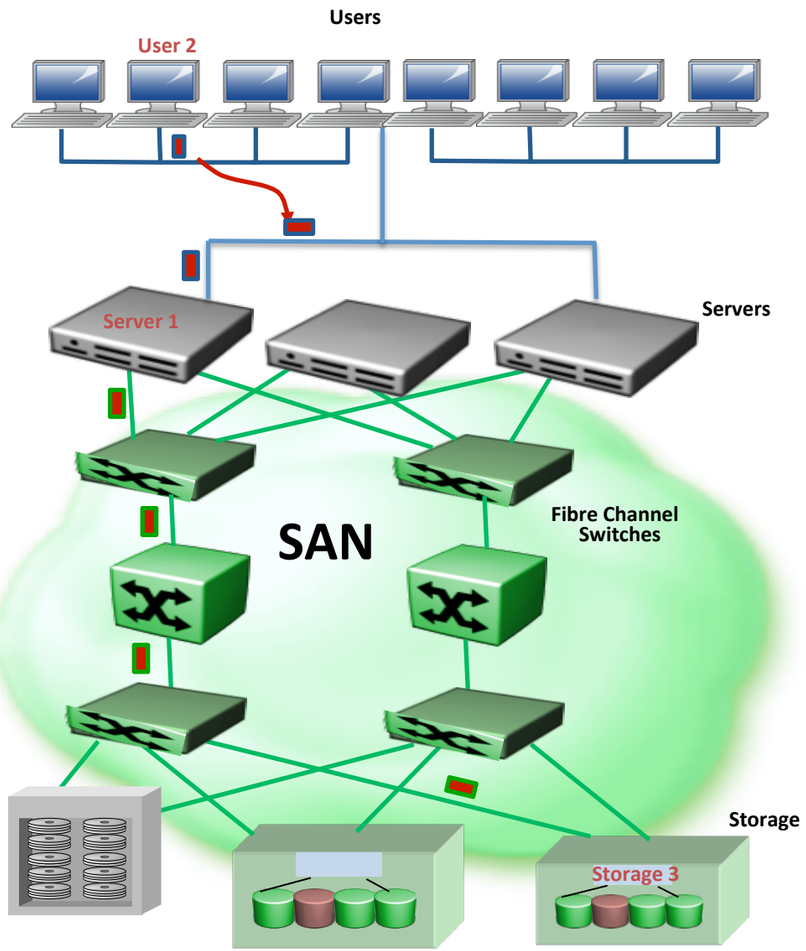
IO Size

IOPs

Throughput

Queue Depth

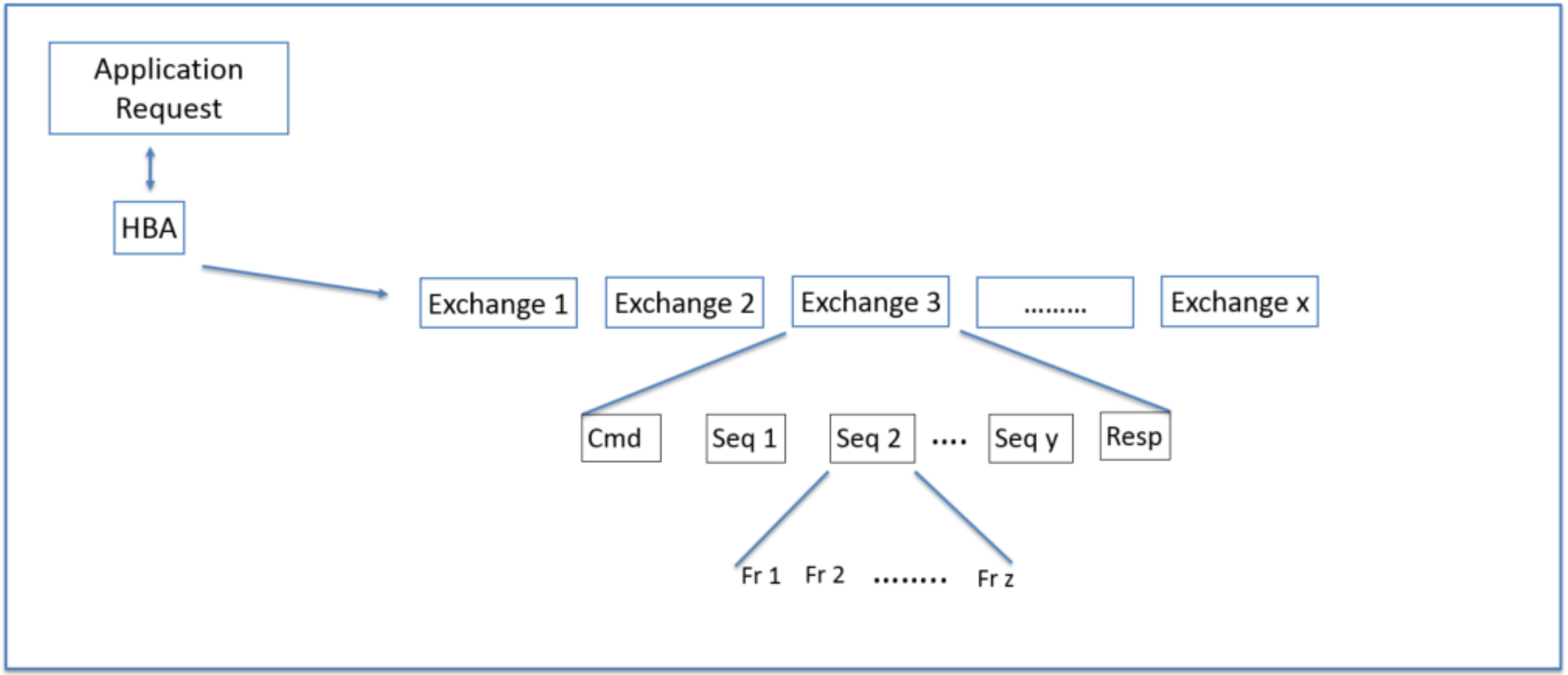
FC4 Mapping – FCP, FC-NVMe



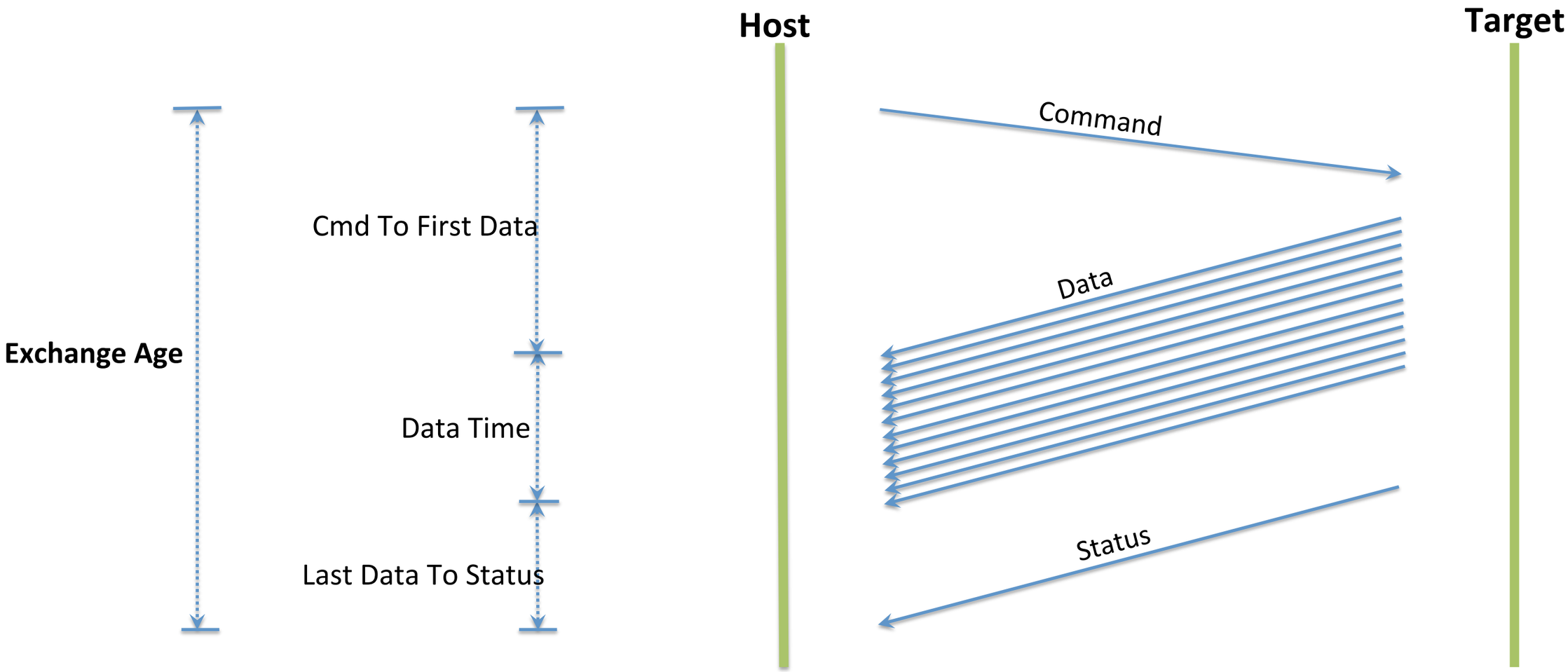
- FCP: SCSI transported over FC
- FC-NVMe: NVMe transported over FC
- One to One Exchange Mapping
- FC Exchange – SCSI Exchange or NVMe Exchange

- User2 requests a document from the storage
- Server 1 sends a request to the SAN
- FC-HBA turns this request into 1 or more FC-Exchanges addressed to Storage 3
- Storage 3 responds with SCSI data frames
- When the Exchange completes, the storage device sends a STATUS frame
- Server 1 accumulates the payload contents and sends the document to User2

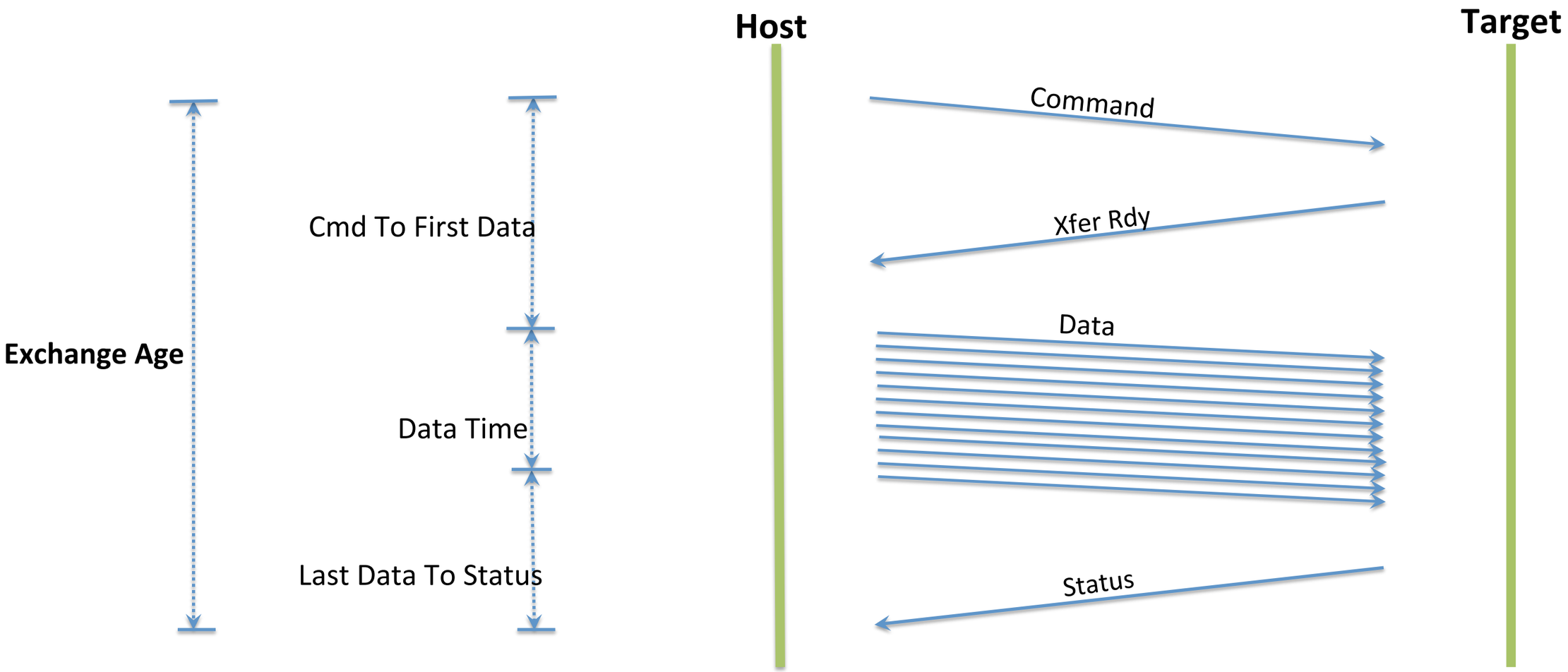
FC Exchange


Application Request
HBA
Exchange 1
Exchange 2
Exchange 3
.....
Exchange x
Cmd
Seq 1
Seq 2
....
Seq y
Resp
Fr 1
Fr 2
.....
Fr z

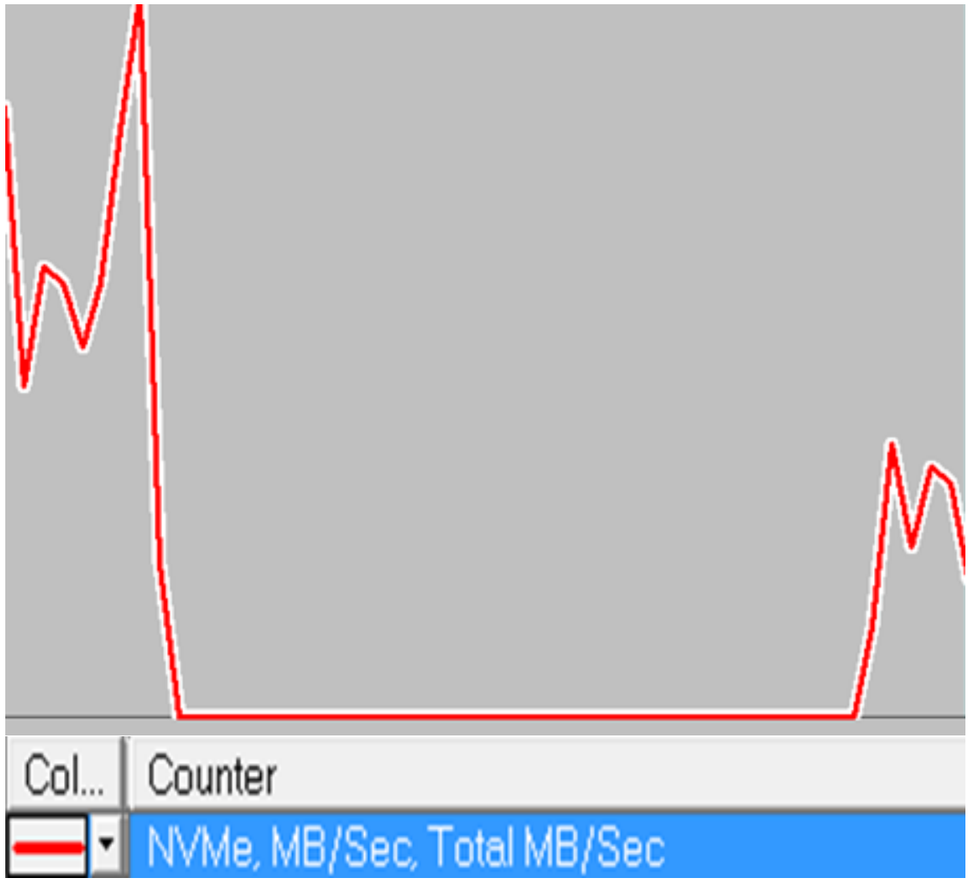
READ- Exchange Timings

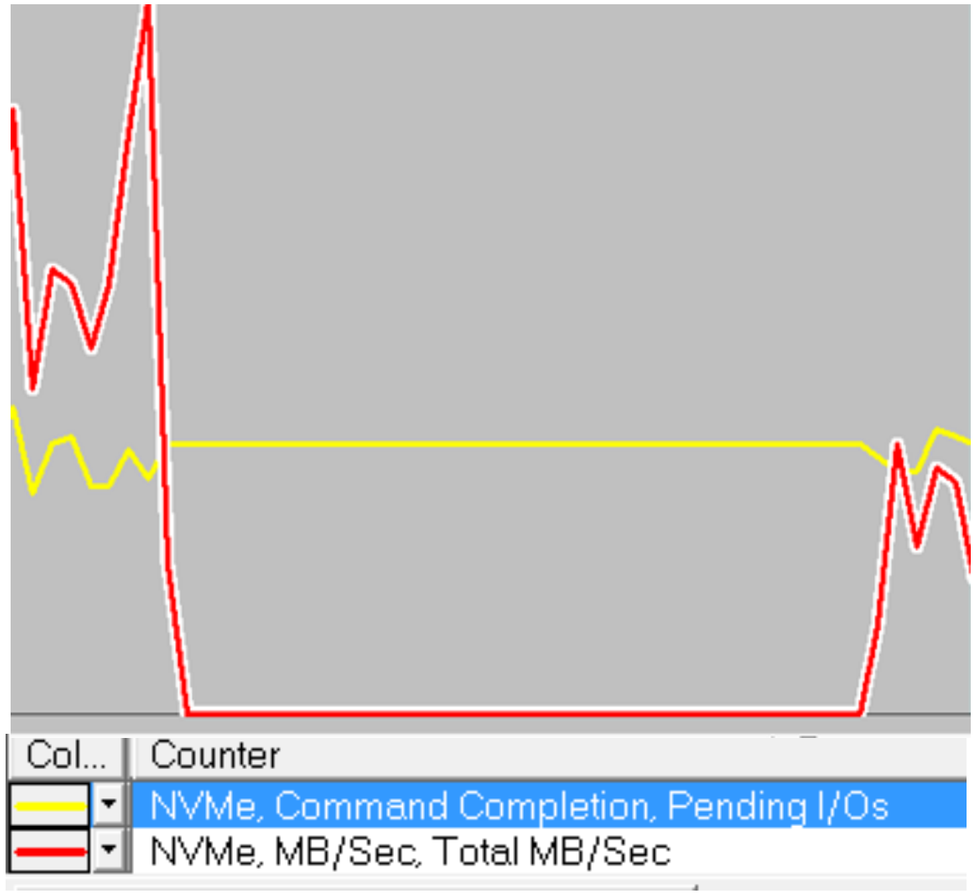


WRITE- Exchange Timings



Debug Example – Exchange Timings



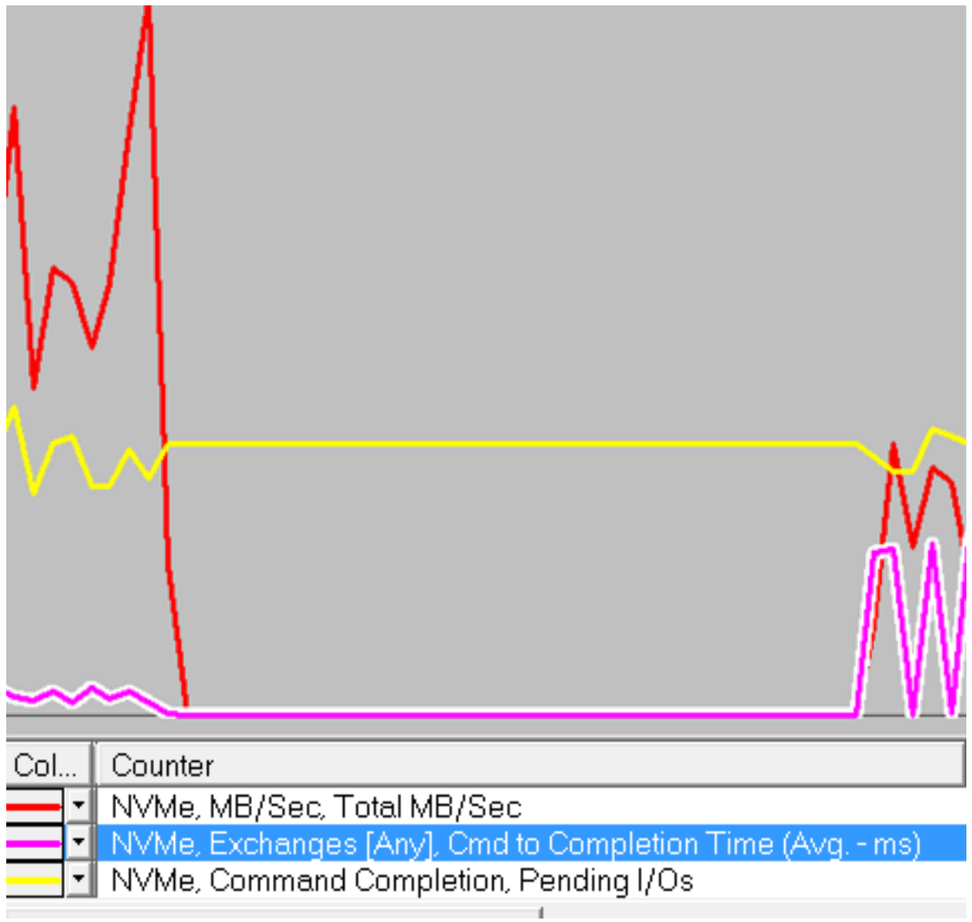


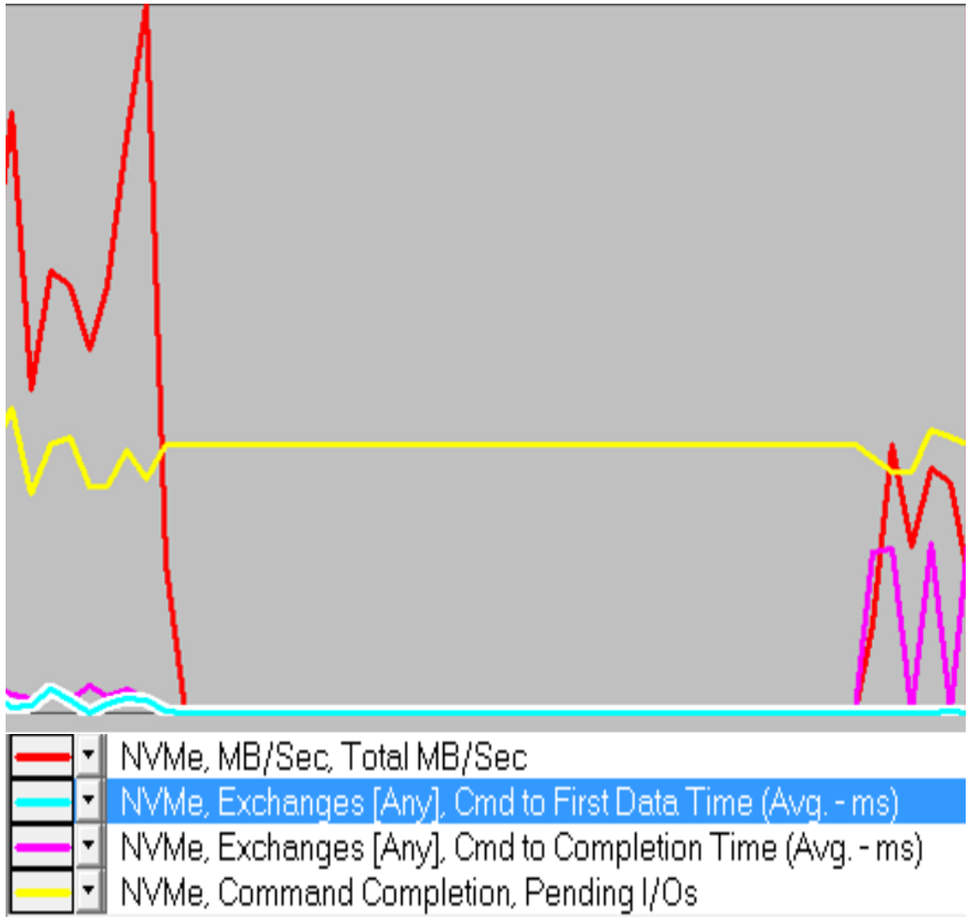
Time

Graph 1: Plot Mb/Sec

Graph 2: Plot Pending I/Os

Debug Example



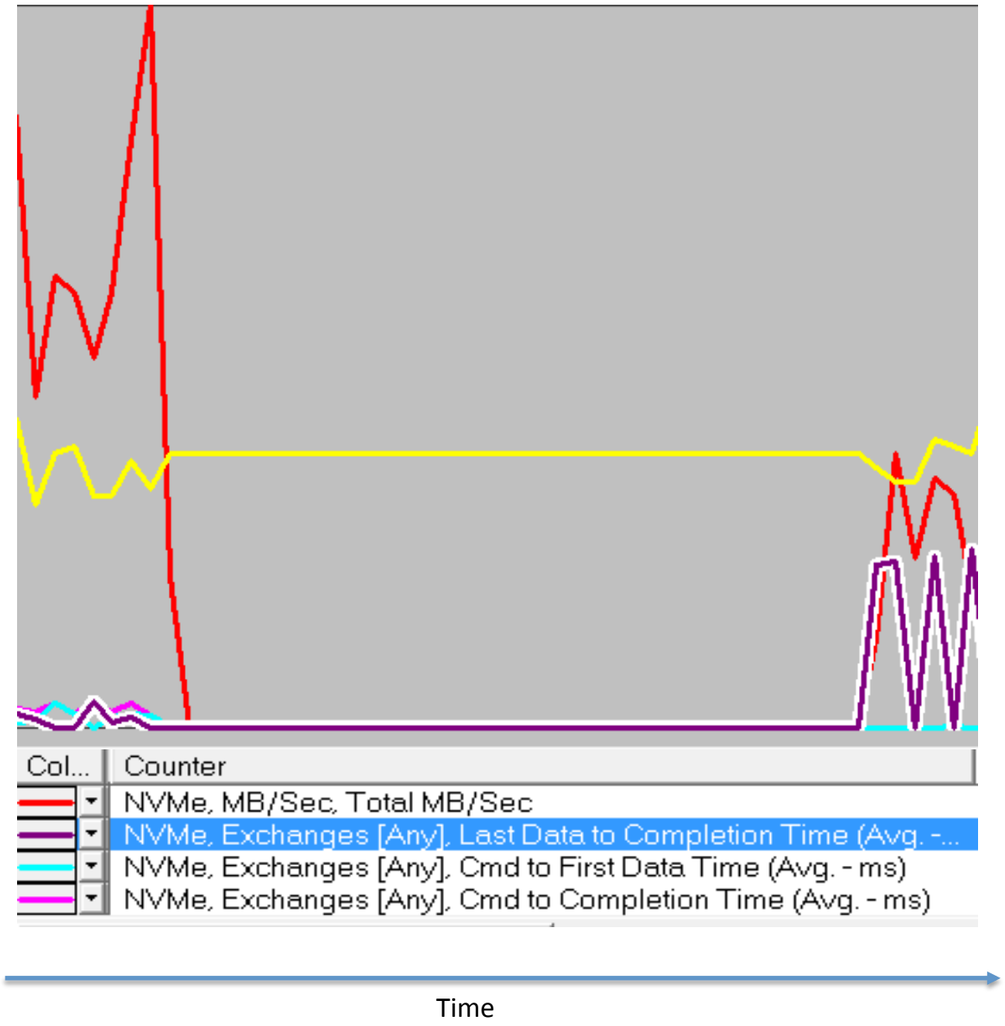


Time

Graph 3: Plot Command To Completion Time

Graph 4: Plot Command To First Data Time

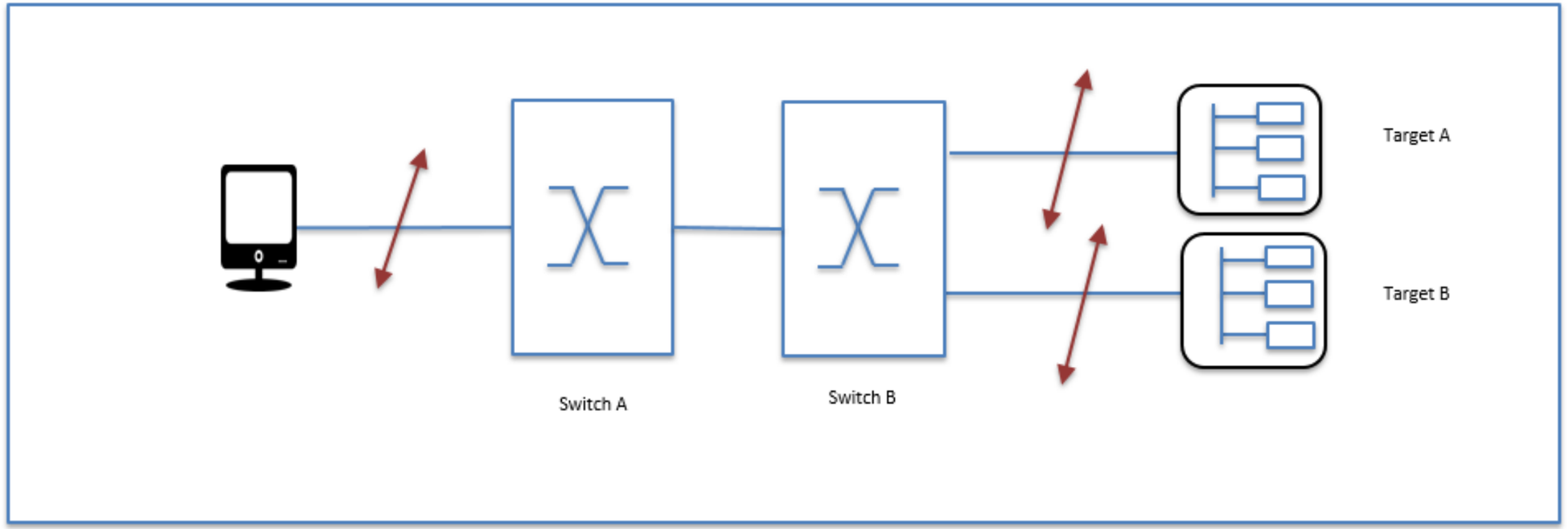
Debug Example



Graph 5: Plot Command To First Data Time

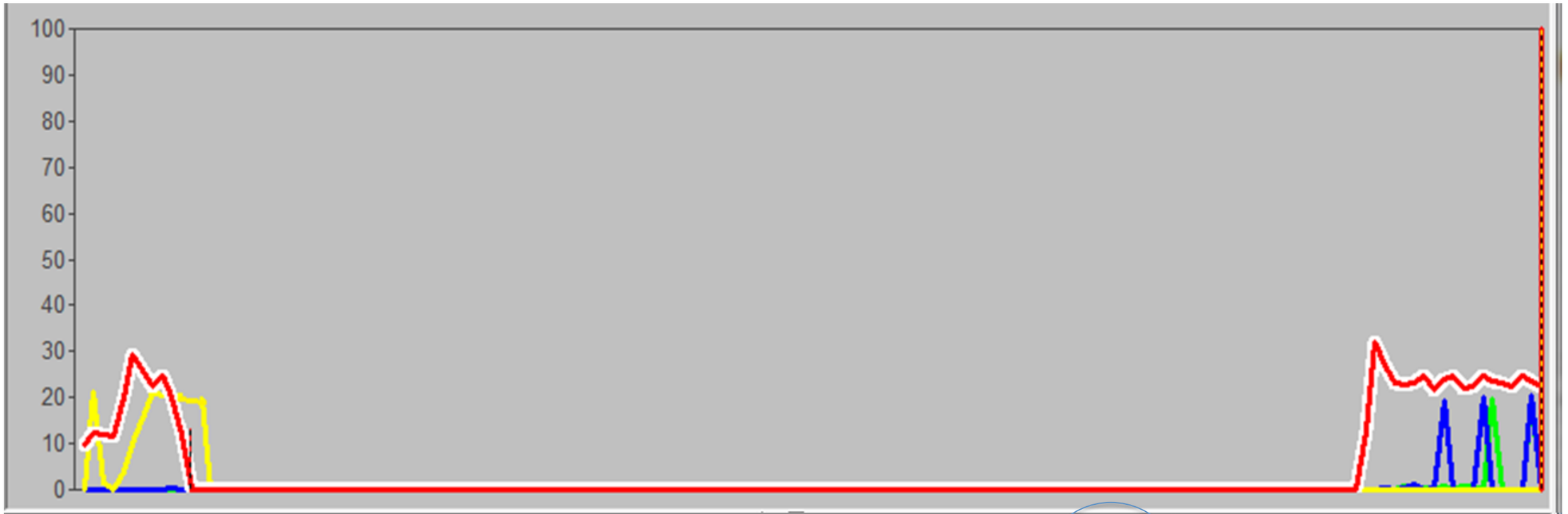
- Exchange Timings can point out topology inefficiencies
- Systematic approach ruling out lower layer issues is important
- Similar symptoms can show due to credit starvation as well

Fabric Congestion



- Analyzer placement should provide an overall view of the topology
- Host to Fabric
- Fabric to Target
- ISL

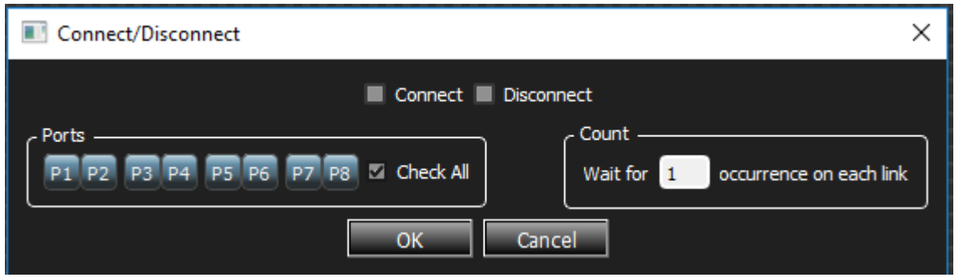
Debug Example - Fabric Delay



Col...	Scale	Counter	Ports	Average	Maximum
	1.0	FCP-SCSI, Exchanges [Total], CMD to First Data Time (Avg. - ms)	1,2,1 / 1,2,2	0.286	19.899
	1.0	FCP-SCSI, Exchanges [Total], CMD to First Data Time (Avg. - ms)	1,2,3 / 1,2,4	0.415	20.556
	0.1	FC, MB/Sec, MB/Sec - All Frames	1,2,1 / 1,2,2	42.962	320.733
	0.1	Cross Port, Port Latency, Latency (Max - us)	Cross Port	11.547	212.140

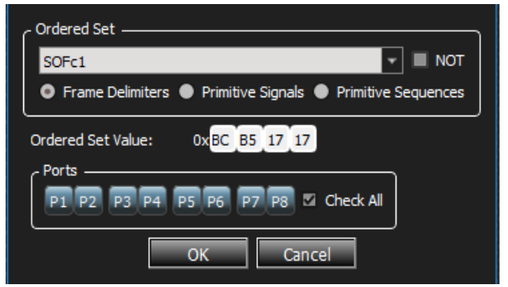
Traffic Modification, aka Jamming

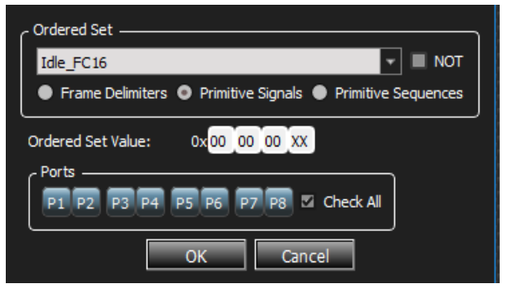
- **Create specific "errors" to test fabrics and their capacity to recover from failure scenarios, examples**;
  - Emulate Cable Pull testing (force disconnect/reconnect)
  - Alter Speed-Negotiation advertisement, add Transmitter Training Errors
  - Alter Primitives
    - Ex. change SoF1 to EOF
  - Introduce latency
- **Establish worse case limitations**
- **Replicate Customer environments/issues**
- **Optimize Error recovery algorithms**

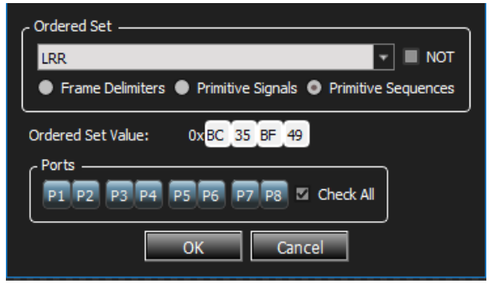


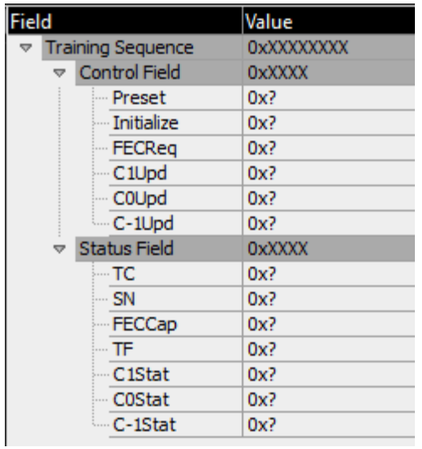
Jamming – FC1 Link Layer

- **Create specific TX/RX conditions to test link recovery**
  - Alter Primitives
  - Remove/Add Frame delimiters
  - Modify CRC or Disparity
  - Force Link Resets
  - Forced TT Errors
- Replicate Customer environments/issues
- Optimize Error recovery algorithms



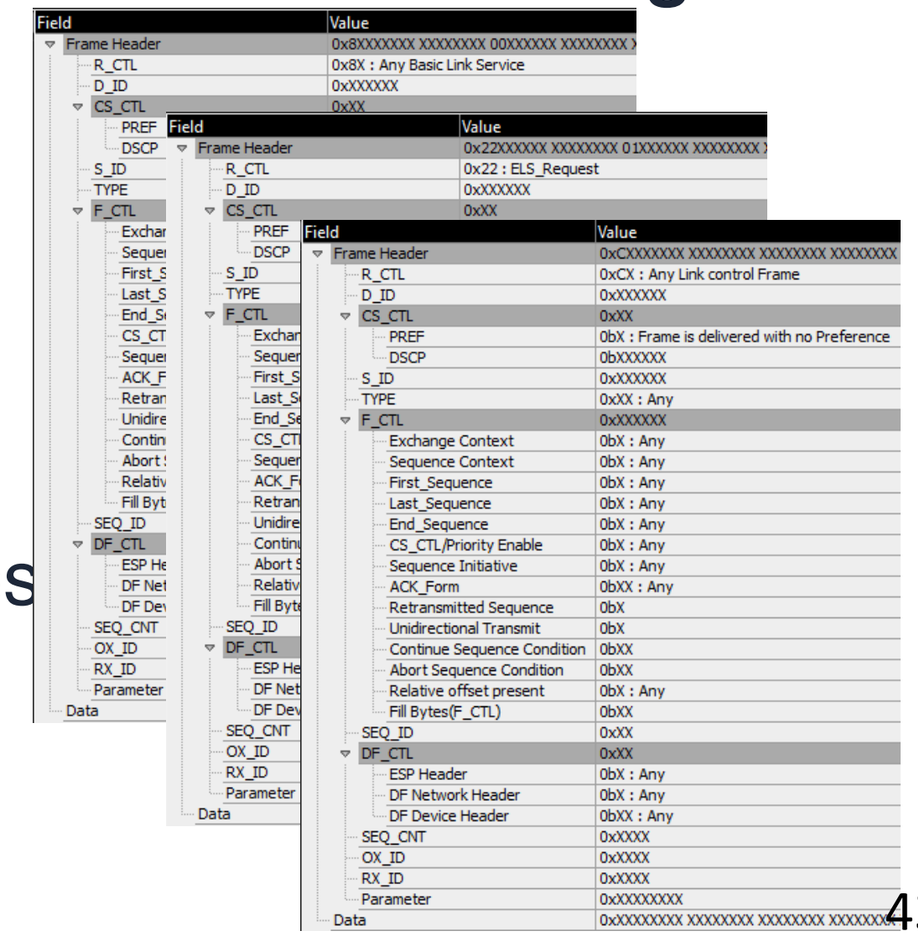






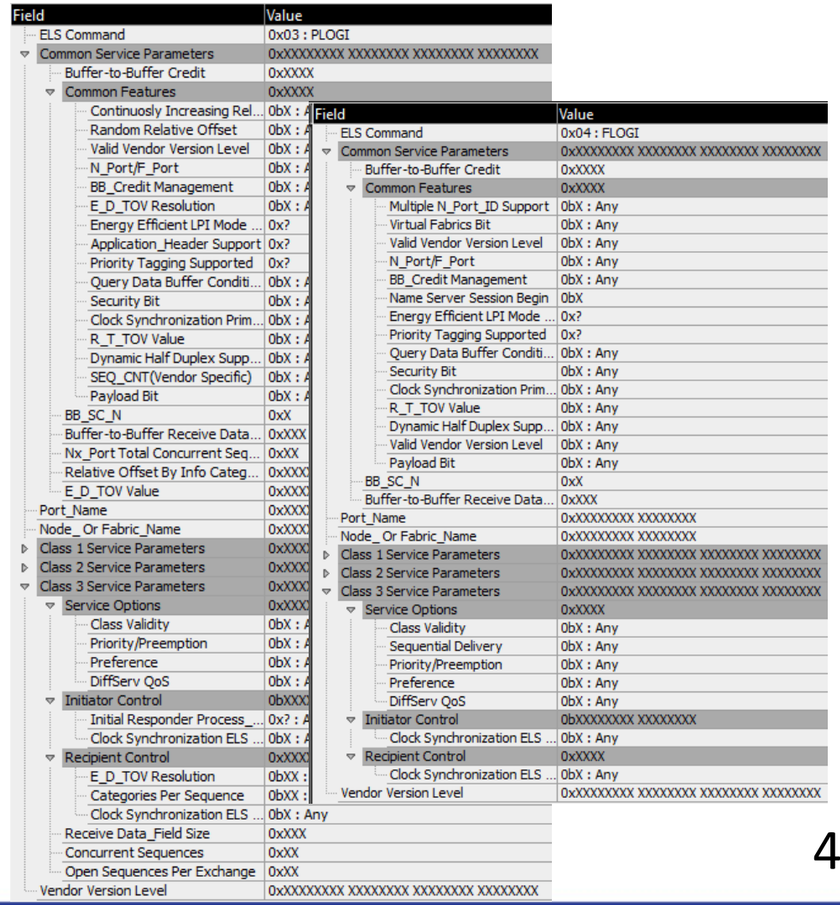
Jamming – FC2 Framing Protocol

- **Create specific Framing/Exchange errors to test framing**
  - Alter Class of Service parameters
  - Change OX_ID or RX_ID information
  - Modify SEQ_ID count
  - Change Frame/Data/Link control values
  - Introduce ABTS
  - Obfuscate Buffer to Buffer Credits
- Replicate Customer environments/issues
- Optimize Error recovery algorithms



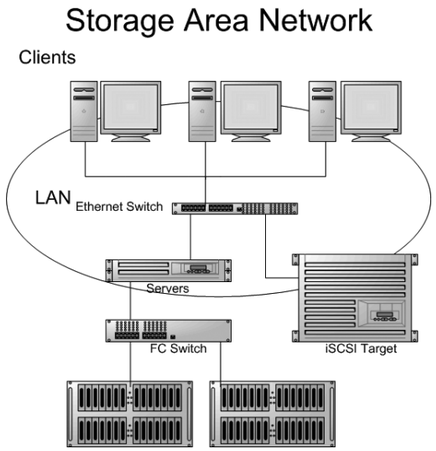
Jamming – FC3 Link Services

- **Create specific Framing/Exchange errors to test basic and extended link services and link controls**
  - Alter Common Service parameters
  - Change PLOGI or FLOGI information
  - Modify N_Port/F_Port values
  - Change SEQ_CNT values
  - Introduce ABTX
  - Change LS_ACC to LS_RJT
- Replicate Customer environments/issues
- Optimize Error recovery algorithms



Jamming – FC4 Application Protocol

- **Create specific Application Protocol command Jams to test latency and recovery**
  - Modify NVMe Submission Queue value
  - Change Set Features to Abort
  - Change Read to Write
- **Validate SAN Stability**



Field	Value
Frame Header	0x06XXXXXX XXXXXXXX 08XXXXX...
R_CTL	0x06 : NVMe_CMND
D_ID	0xXXXXXX
CS_CTL	0xXX
PREF	0bX : Frame is delivered with no ...
DSCP	0bXXXXXX
S_ID	0xXXXXXX
TYPE	0x08 : Fibre Channel Protocol
F_CTL	0xXXXXXX
Exchange Context	0bX : Any
Sequence Context	0bX : Any
First_Sequence	0bX : Any
Last_Sequence	0bX : Any
End_Sequence	0bX : Any
CS_CTL/Priority Enable	0bX : Any
Sequence Initiative	0bX : Any
ACK_Form	0bXX : Any
Retransmitted Sequence	0bX
Unidirectional Transmit	0bX
Continue Sequence Condition	0bXX
Abort Sequence Condition	0bXX
Relative offset present	0bX : Any
Fill Bytes(F_CTL)	0bXX
SEQ_ID	0xXX
DF_CTL	0xXX
ESP Header	0bX : Any
DF Network Header	0bX : Any
DF Device Header	0bXX : Any
SEQ_CNT	0xXXXX
OX_ID	0xXXXX
RX_ID	0xXXXX
Parameter	0xXXXXXXXX
Data	0xXXXXXXXX XXXXXXXX XXXXXXX...

Field	Value
NVMe_CMND IU Header	0xXXXXXXXX XXXXXXXX XXXXXXXX ...
SCSI Identifier	0xXX
FC Identifier	0xXX
CMND IU Length	0xXXXX
Flags	0xXX
NVMe Connection Identifier	0xXXXXXXXX XXXXXXXX
Command Sequence Number	0xXXXXXXXX
Data Length	0xXXXXXXXX
NVM Submission Queue Entry	0x02XXXXXX XXXXXXXX XXXXXXXX ...
NVMe PDU	0x02XXXXXX XXXXXXXX XXXXXXXX ...
Data	0xXXXXXXXX XXXXXXXX XXXXXXXX ...

Field	Value
NVMe Header	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXX...
SQE	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXX...
Command	0xXXXXXX02
OPCode	0x02 : Read
FUSE	0x? : Any
PSDT	0x? : Any
CID	0xXXXX
NSID	0xXXXXXXXX
MPTR	0xXXXXXXXX XXXXXXXX
DPTR	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX
PRP1	0xXXXXXXXX XXXXXXXX
PBAO	0x?XXXXXXX XXXXXXXX
PRP2	0xXXXXXXXX XXXXXXXX
PBAO	0x?XXXXXXX XXXXXXXX
SLBA	0xXXXXXXXX XXXXXXXX
NLB	0xXXXX
PRINFO	0xX
FUA	0x?
LR	0x?
DSM	0xXX
Access Frequency	0xX : No frequency information provided
Access Latency	0x? : Any
Sequential Request	0x?
Incompressible	0x?
EILBRT	0xXXXXXXXX
ELBAT	0xXXXX
ELBATM	0xXXXX
Data Payload	0xXXXXXXXX XXXXXXXX XXXXXXXX XXXXXXX...

Questions??

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