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IBM System z Long Distance Extension and FCIP Network Primer

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Brocade Communications

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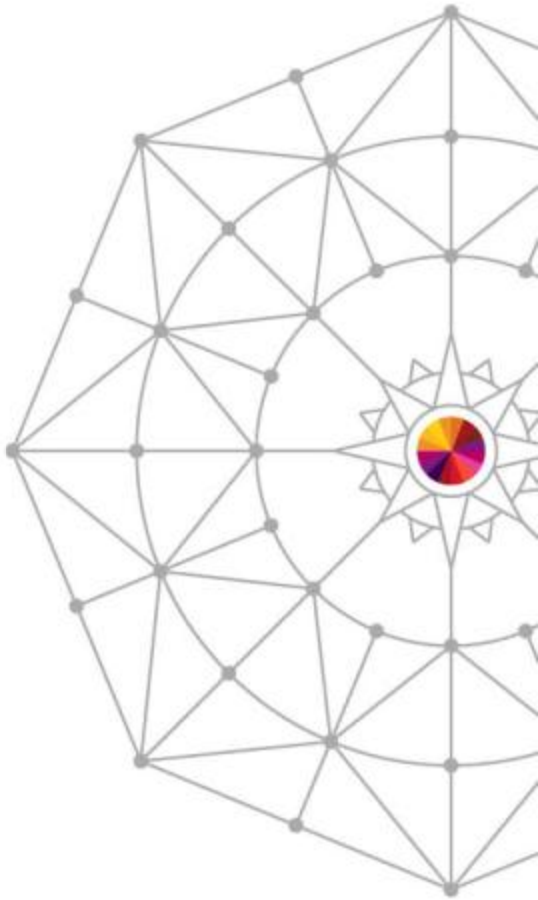


SHARE in Anaheim

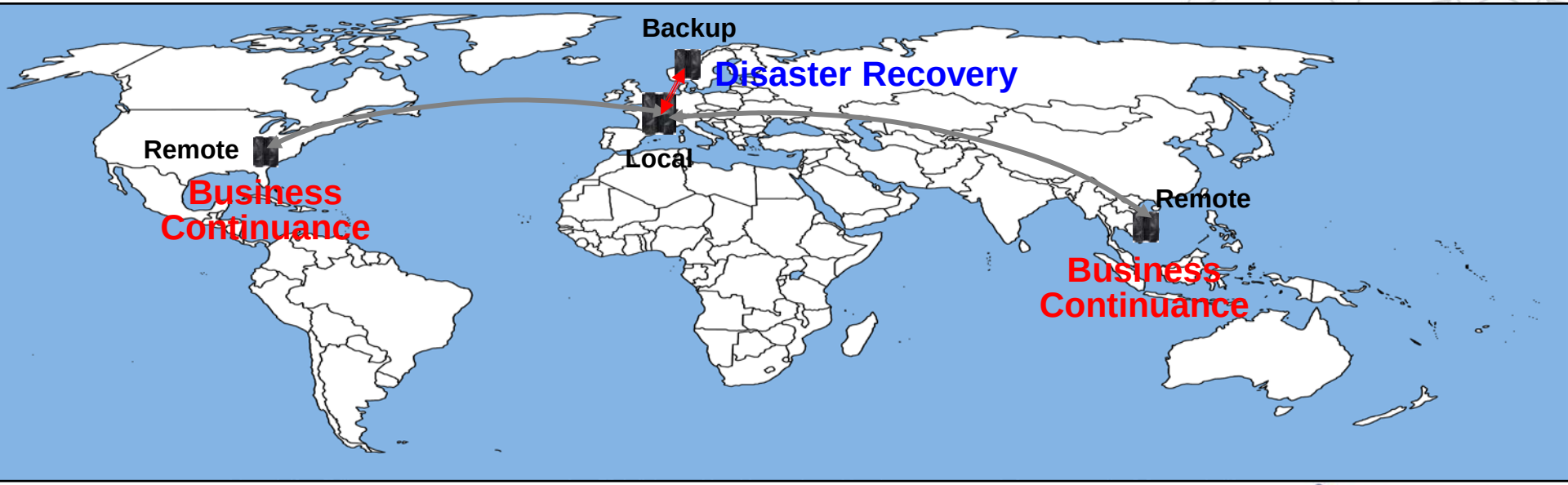
Abstract

- This session will discuss Fibre Channel over IP (FCIP) networking for IBM System z environments. We will discuss basics, such as tunnels, circuits, and the protocol itself. We will also cover several more advanced technical subjects, such as FCIP trunking, metrics/failover, lossless link loss, and how TCP plays a role in FCIP networks. Finally, we will discuss different FICON protocol emulation techniques used to improve performance over very long distances.
- Specific hardware product references will be discussed when applicable.

Agenda

- Basics-standards/protocol, tunneling , circuits, batching
- The role TCP plays with FCIP
- FCIP trunking, metrics/failover, and lossless link loss
- FICON protocol emulation: improved long distance performance

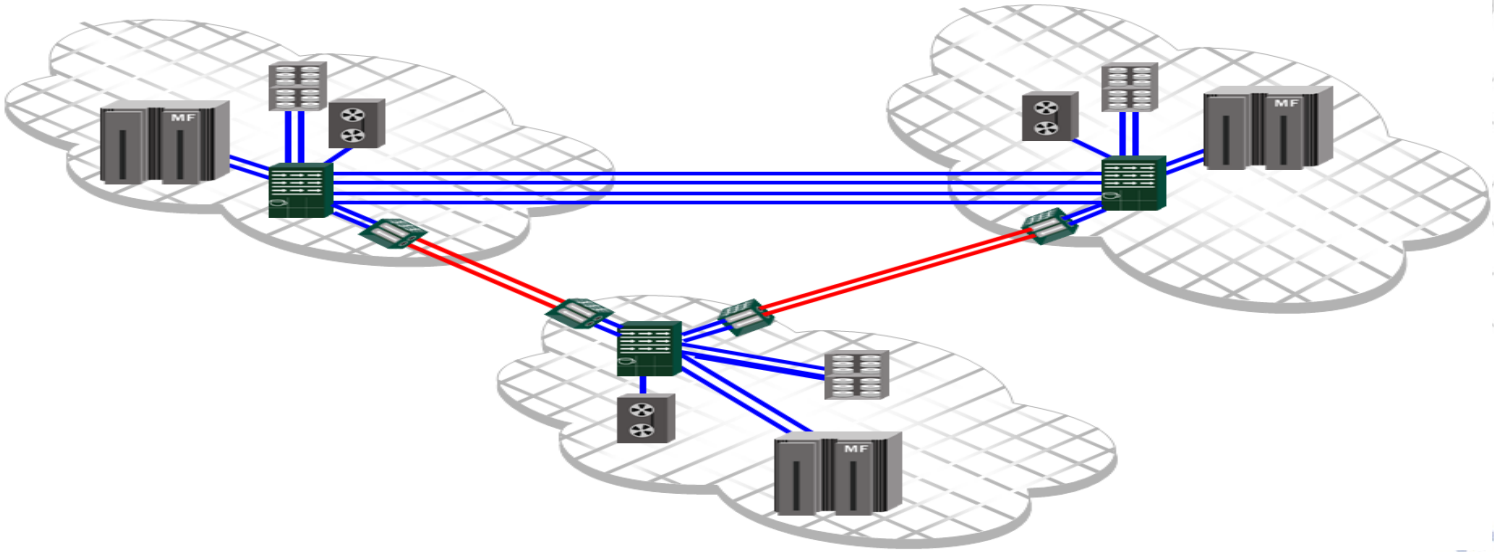
FCIP Basics: Standards, Protocol, Tunneling, Circuits and Batching



FCIP Long Distance Cascading

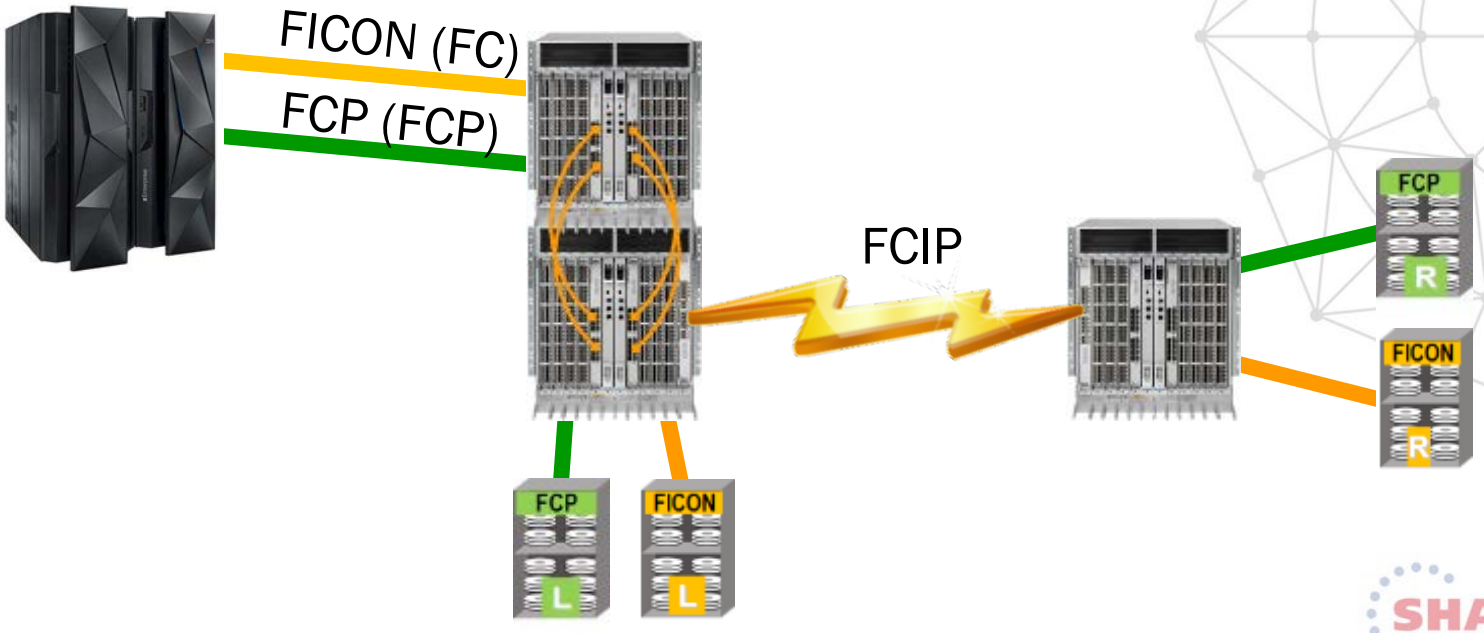
- Distance Extension for Thousands of Miles of Connectivity

- Fibre Channel over IP (FCIP) enables interconnection of two switched FC fabrics using TCP/IP that is transparent to the FC fabric switches, storage devices, and users.



FCIP use cases

- Mainframe FCIP supports remote data replication (RDR), global mirror z/OS (zGM or XRC), Geographically Dispersed Parallel Sysplex (GDPS) and channel-to-channel (CTC) attachments for parallel sysplex.



Why Fibre Channel over IP?

- Why FCIP instead of extended native FC?
  - Cost of IP bandwidth vs. FC bandwidth
  - Eliminate distance constraints
  - Leverage investment in existing IP network
  - IP ubiquity – it is just everywhere!
  - Reduce consumption of fiber
- Dramatically improve recovery time with reasonable cost
  - Recovery in hours vs. days as required with manual off-site vaulting
  - Less cost to backup multiple applications with in-house Disaster Recovery versus a single application performed by a 3rd party data warehousing company

Standards and FCIP

- Fibre Channel over TCP/IP (FCIP) is IETF RFC 3821
  - July 2004
- Relevant Fibre Channel standards include, but are not limited to:
  - FC-BB series (Fibre Channel Backbone)
  - FC-SW series (Fibre Channel Switch Fabric)
  - FC-FS series (Fibre Channel Framing and Signaling)

- The FC-BB series is the Fibre Channel documentation describing the relationships between FC and TCP/IP

FCIP Overview

- Fibre Channel over IP is a mechanism that allows mainframe FICON as well as SAN islands and ports to be interconnected over IP networks.
- Each interconnection is called an FCIP Link and can contain one or more TCP connection(s).
- Each end of a FCIP Link is associated to a logical *Virtual E_Port* (VE_Port).
- VE_Ports communicate between themselves just like normally interconnected E_Ports
- The result is a ***fully merged*** Fibre Channel fabric.

FC data is encapsulated within IP packets and TCP frames

FCIP Overview

- Fibre Channel over IP (FCIP) enables customers to use their IP wide area network (WAN) infrastructure to connect Fibre Channel SANs while keeping the targets and initiators unaware of the presence of the WAN in the data path

- FCIP supports applications such as remote data replication (RDR), centralized SAN backup, and data migration over very long distances and can provide improved performance when compared to typical long distance ISL links

- FCIP tunnels are used to pass Fibre Channel I/O through an IP network.
  - FCIP tunnels are built on a physical connection between two peer switches or blades.

- FC frames enter FCIP through virtual E_Ports (VE_Ports)
  - Frames are encapsulated and passed to the Transmission Control Protocol (TCP) layer connections.

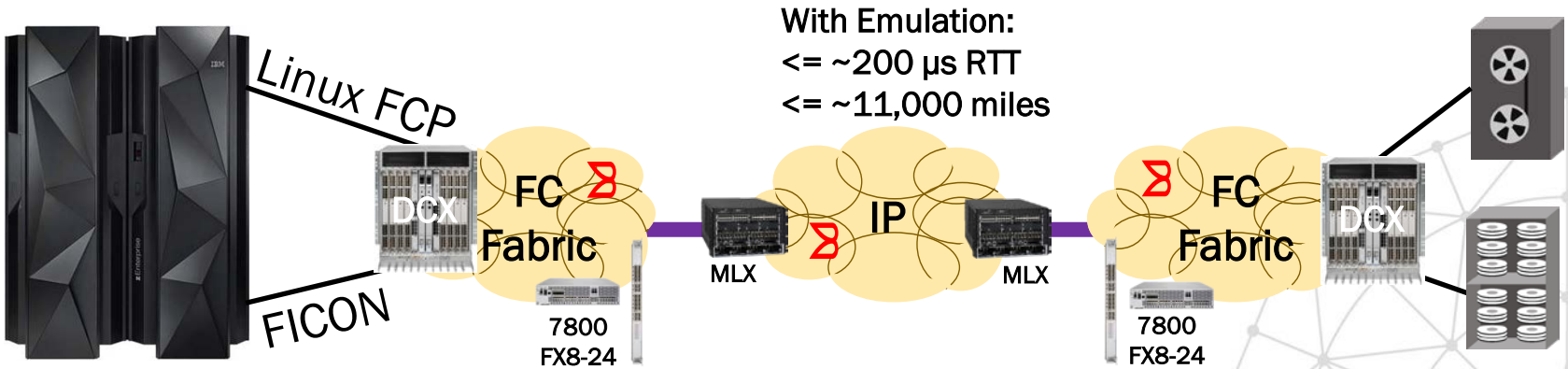
The role TCP plays in FCIP

- Viewed from the IP Network perspective, FCIP entities are peers and communicate using TCP/IP.
- TCP/IP is used as the underlying transport to provide congestion control and in-order delivery of error-free data.
  - If FC was really being managed by IP there could be many frame drops. TCP prevents this.
  - The TCP connections ensure in-order delivery of FC frames and lossless transmission.
- FCIP may use TCP/IP quality of service features (QoS)

FCIP Tunnels and Protocol Stack

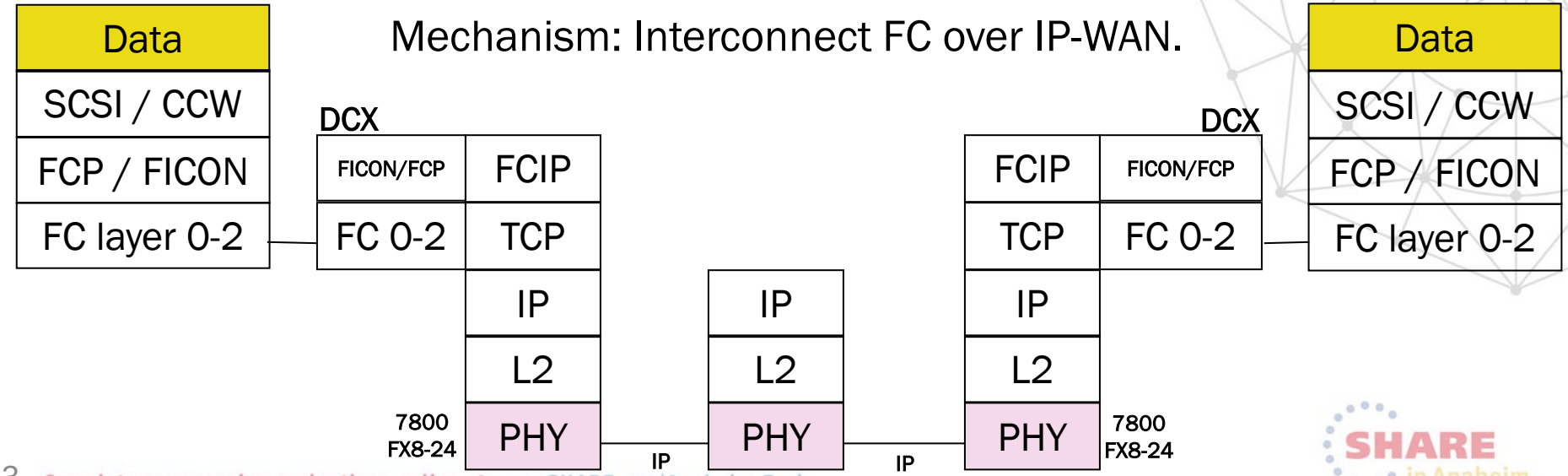
- Before a FC frame is sent out via FCIP, the transmitting FCIP port **encapsulates** the FC frame within the four protocols in the stack:
  - FCIP, TCP, IP and Ethernet
- The receiving FCIP port strips the Ethernet, IP, TCP, and FCIP headers; reassembles the FC frame if it was split among more than one segment; and forwards the FC frame into the FC fabric
- As you will soon see, tunnels can be trunked. Since an I/O exchange will be spit between the tunnels in a trunk, an exchange will see an aggregate of all the FCIP Trunk bandwidth and probably not suffer from bandwidth constraints

FC over IP (FCIP)
Fibre Channel to Ethernet and Back Again



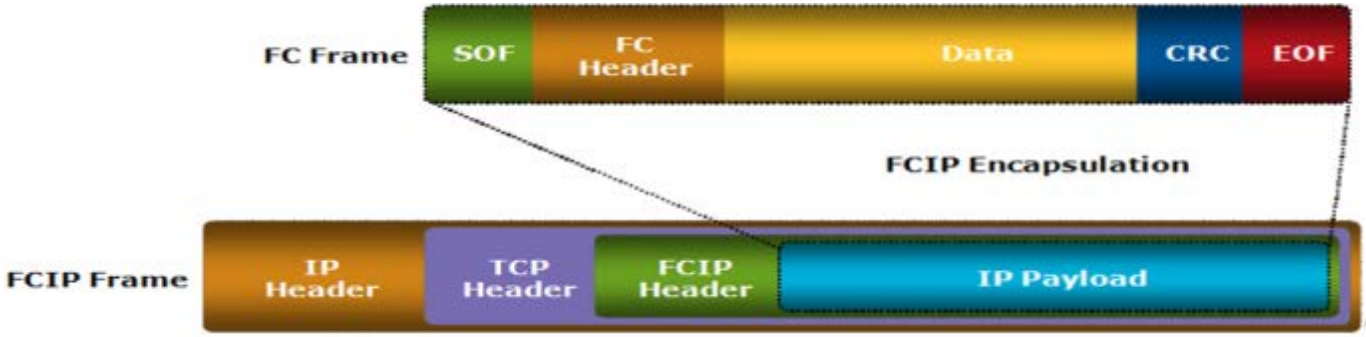
An IP tunnel for FC-based Storage Network

Mechanism: Interconnect FC over IP-WAN.



Creating an FCIP Frame

- Deploying standard FCIP provides users with very poor performance



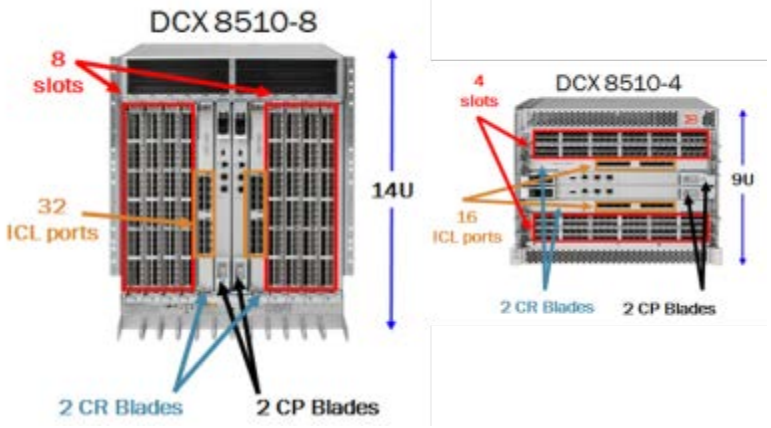
One IP frame for each FICON frame.

- With Brocade, FC frames are encapsulated within IP packets
  - A compressed, FICON batch (many frames) is encapsulated per IP frame
  - Receiver removes the IP and TCP wrappers and sends FC data into the fabric

- Our method provides security, data integrity, and performance

Brocade FCIP Hardware Components

Resilient, synergistic networks



DCX 8510 Gen5 FICON/FCP Directors

MLX Series High-Performance, Multiservice Routers

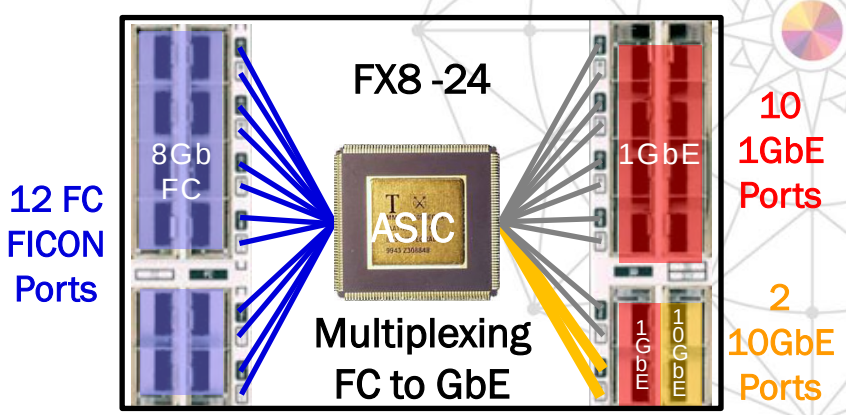
Ultra High Performance, Superior RAS

FX8-24 Extension Blade

7800 Extension Switch

Brocade FCIP Devices 7800 switch and FX8-24 blade

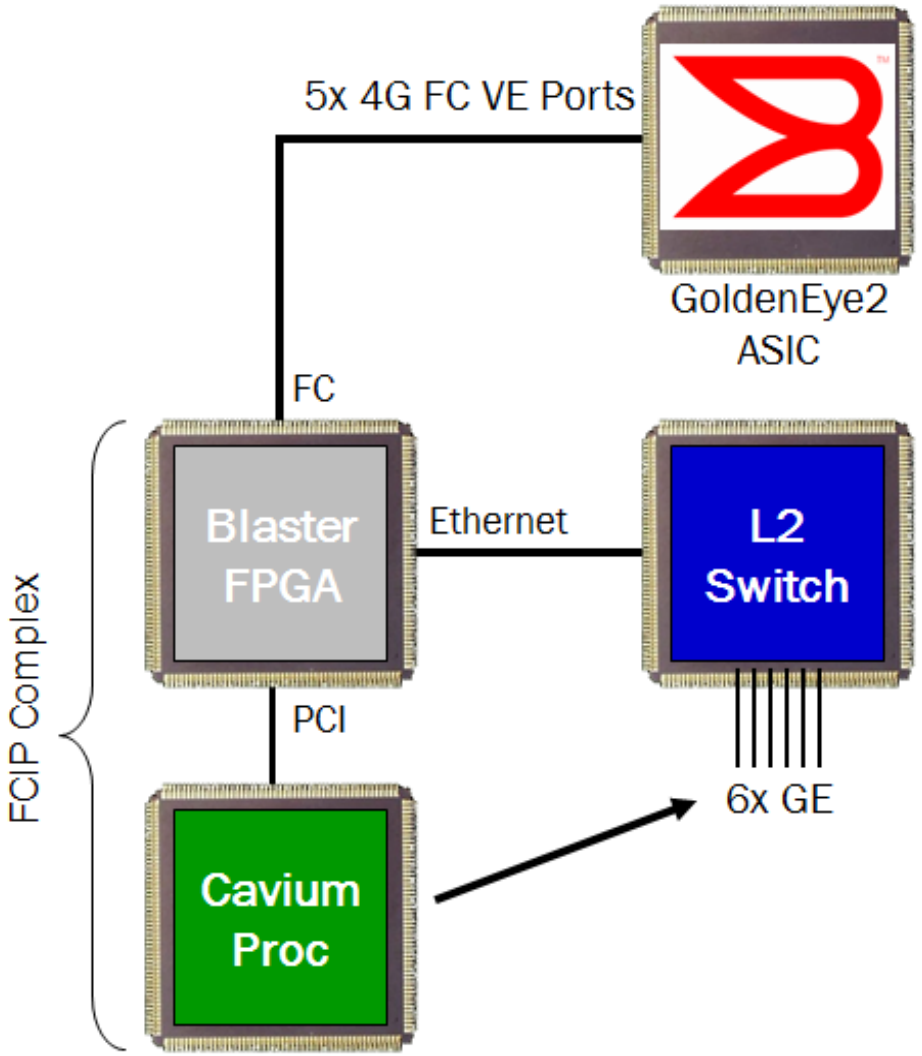
- Internal to 7800 and FX8-24 there are Brocade ASICs (Application-Specific Integrated Circuits) that Brocade calls GoldenEye2 (GE2) for the Brocade 7800 and the Condor2 (C2) for the Brocade FX8-24.
- These ASICs know only about Fibre Channel (FC) protocol.
- The Virtual Expansion Ports (VE) are logical representations of actual FC ports on those ASICs
  - Think of VE_Ports as the transition point from the FC world to the TCP/IP world inside these devices.
  - In actuality, multiple FC ports feed a VE_Port, permitting data rates well above 8 Gbps, which is necessary to attain full utilization of the 10 Gigabit Ethernet (GbE) FCIP interfaces on the Brocade FX8-24
  - Multiplexing FC ports into the GbE ports is also necessary for feeding the FCIP compression engine at high data rates.



~50 µs latency to go from a FC frame to an FCIP frame

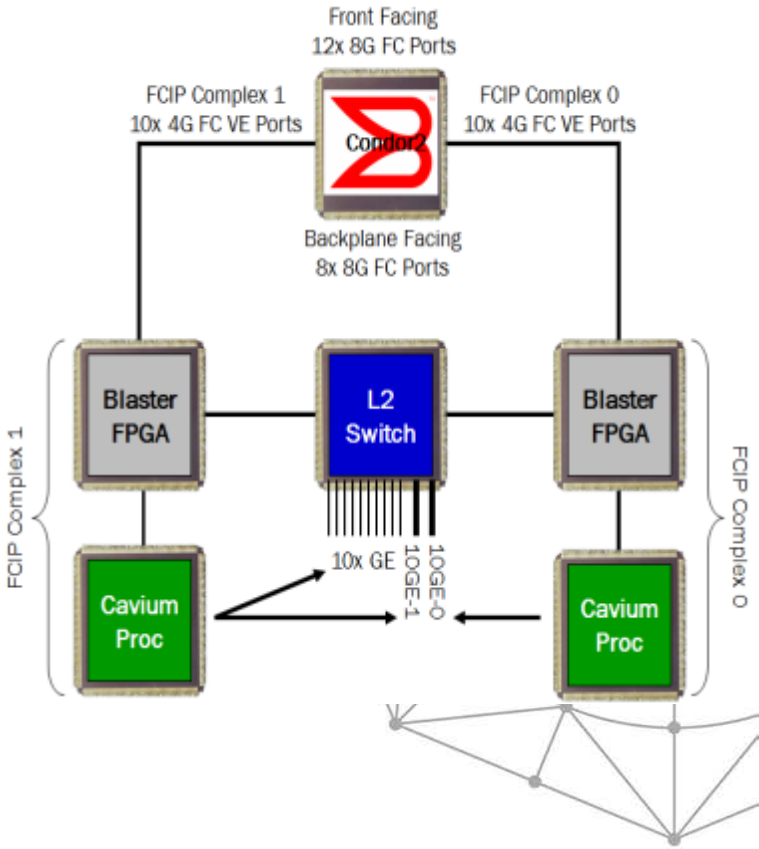
Brocade FCIP 7800 Considerations

- Logical Virtual Expansion Ports (VE_Ports) are really E_Ports on the Condor2 (C2) ASIC that are FCIP facing.
- A 7800 switch supports up to 10 VE_Ports, and therefore 10 FCIP tunnels, one each on the 1 GbE ports
- There is a single processor complex (FPGA and Cavium processor) on a 7800.
- This processor complex provides the FCIP processing engine



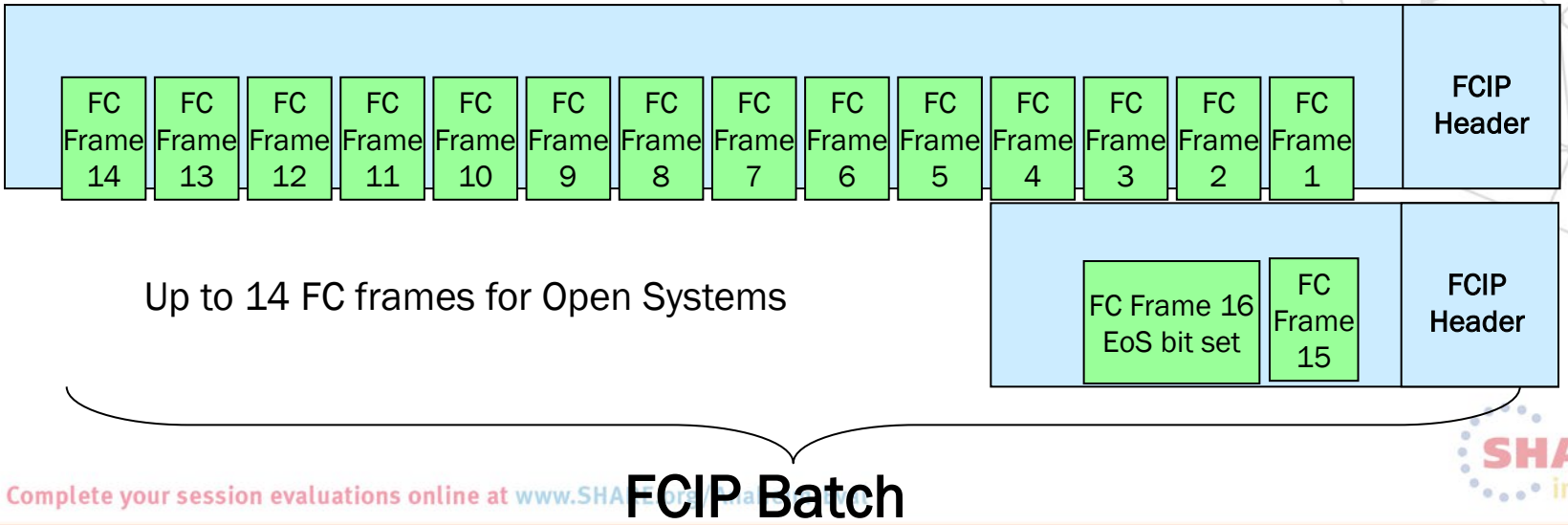
Brocade FCIP
FX8-24 Blade Considerations

- An FX8-24 blade supports up to 20 VE_Ports, and therefore 20 FCIP tunnels.
  - One each on the 1 GbE ports
  - Ten on each of the two 10 GbE ports
- There are two processor complex's (FPGA and Cavium processor) on an FX8-24
- These provide the FCIP processing engines
- On the FX8-24 blade there are two VE_Port groups:
  - 12 through 21 (10 tunnels) through the first processor on the blade
  - 22 through 31 (10 tunnels) through the second processor on the blade
- Each FCIP tunnel is associated with a specific VE_Port:
  - GE mode: VE_Ports 12-21 use GE 0-9
  - 10GE mode: VE_Ports 12-21 use xge1; VE_Ports 22-31 use xge0
  - Dual mode: VE_Ports 12-21 use GE 0-9; VE_Ports 22-31 use xge0



FCIP Batches
A Brocade Exclusive Capability

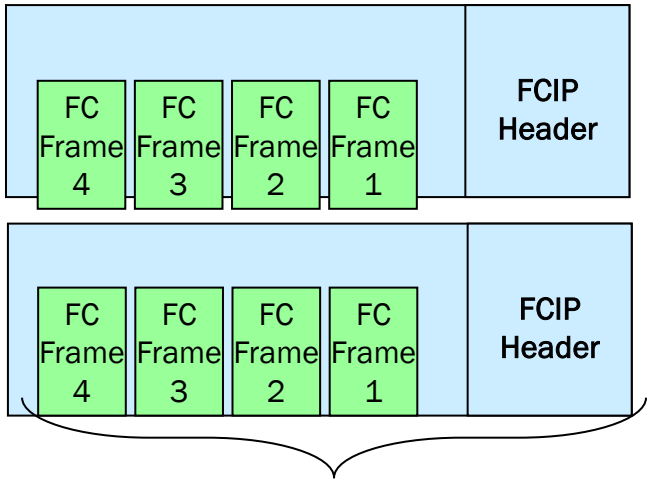
- The Brocade 7800 and FX8-24 use batching to improve overall efficiency, maintain full utilization of links, and reduce protocol overhead.
  - Simply put, a batch of FC frames is formed, after which the batch is processed as a single unit.
- Batching forms FCIP frames at one frame per batch. A batch is comprised of up to fourteen FC frames that have already been compressed using the exclusive Brocade FCcomp technology.
  - Compression adds 2-4µs additional latency while encryption adds 5µs more latency
- All the frames have to be from the same exchange's data sequence.



FCIP Batches
A Brocade Exclusive Capability

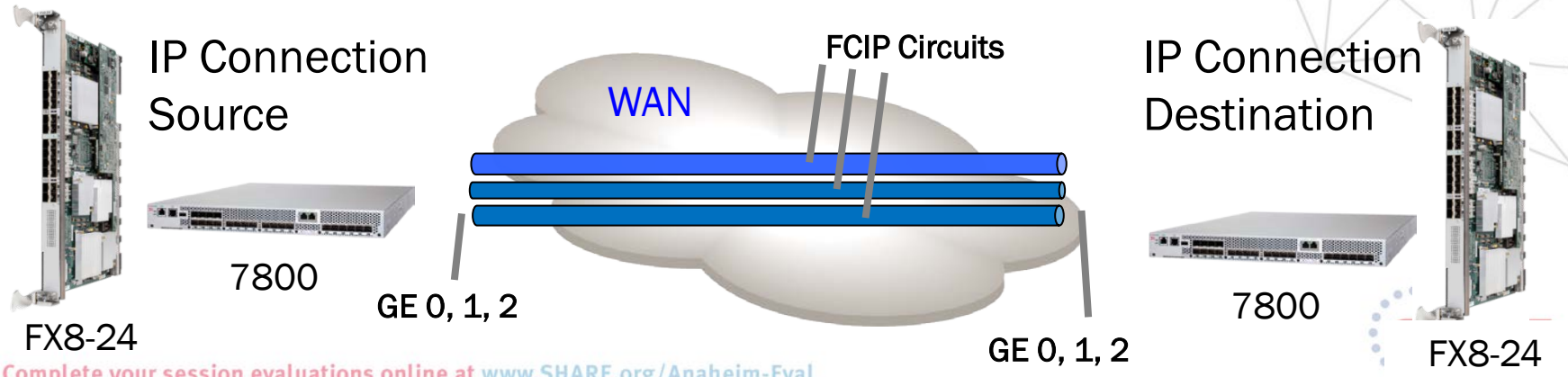
- Up to 4 FC frames in a FICON batch
  - 4 FICON frames get 1 FCIP header and they form a string of bytes that is then placed in TCP segments up to the maximum segment size.
- Up to 14 FC frames in a Open Systems batch
- Compression occurs first upon frame's FC ingress before creating a batch
- All frames are from the same exchange
- Only data FC frames are batched
- Processed as a single entity
- End of Sequence bit in FC frame causes immediate send

Up to 4 FC frames for FICON per Batch



FCIP Circuits

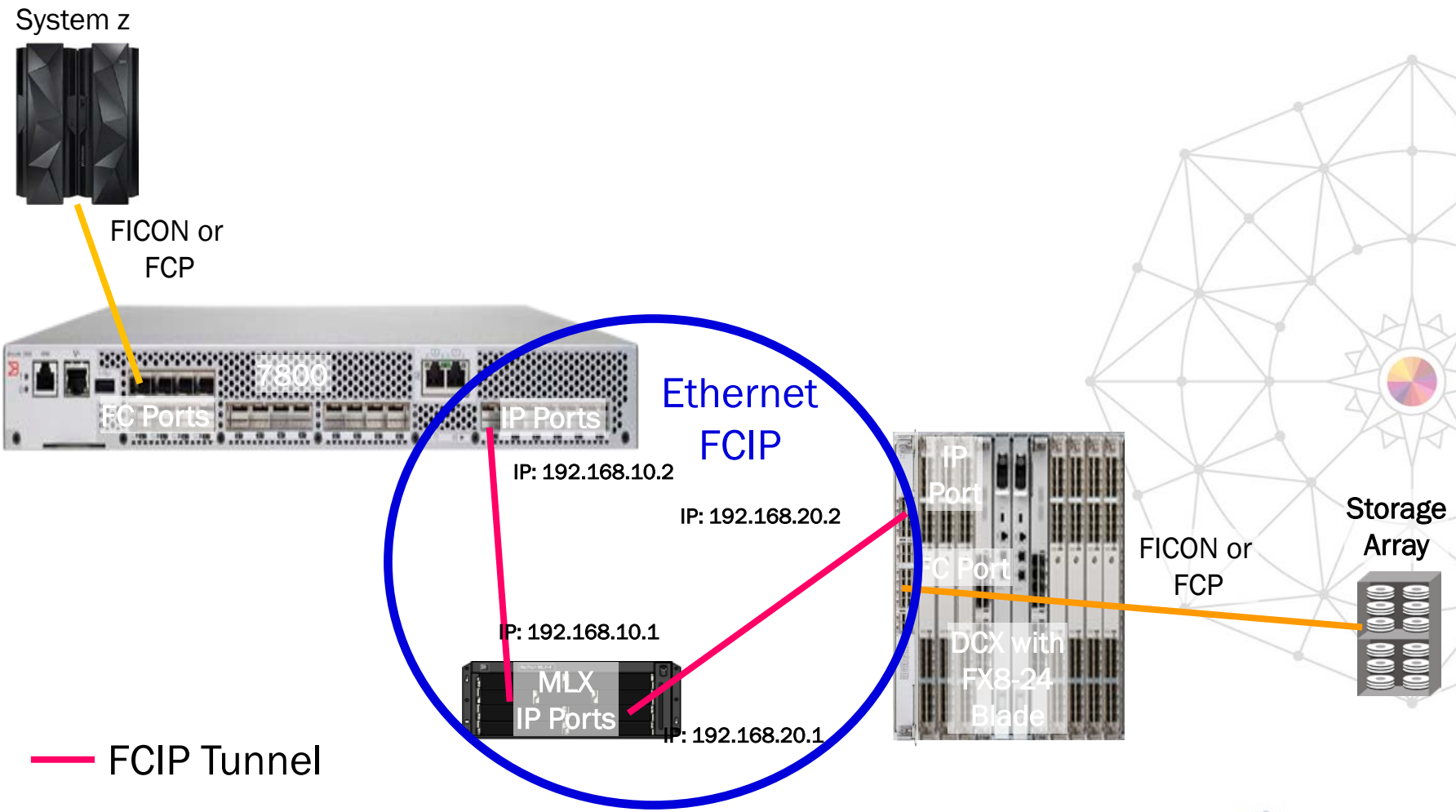
- FCIP Circuits are the building blocks for FCIP Tunnels and FCIP Trunking
- An FCIP Circuit consists of a source and destination IP address pair
  - The circuit is an FCIP connection between two unique IP addresses
- An Ethernet port can contain one or more circuits – each requiring a unique IP Address:
  - Up to six FCIP circuits can be configured per 1 GbE port
  - Up to ten FCIP circuits can be configured per 10 GbE port
- Each circuit automatically creates multiple TCP connections that can be used with QoS prioritization



FCIP Tunnels and Protocol Stack

- Once a TCP connection is established between FCIP entities, a **Tunnel** is established:
  - The two platforms (blade or extension switch) at the FCIP tunnel endpoints establish a standard FC inter-switch link (ISL) through this tunnel.
  - Each end of the FCIP tunnel appears to the IP network as a server, not as a switch
  - The FCIP tunnel itself appears to the switches to just be a cable
- Each tunnel carries a single FC ISL:
  - Load balancing across multiple tunnels is accomplished via FC mechanisms just as would be done across multiple FC ISLs in the absence of FCIP.

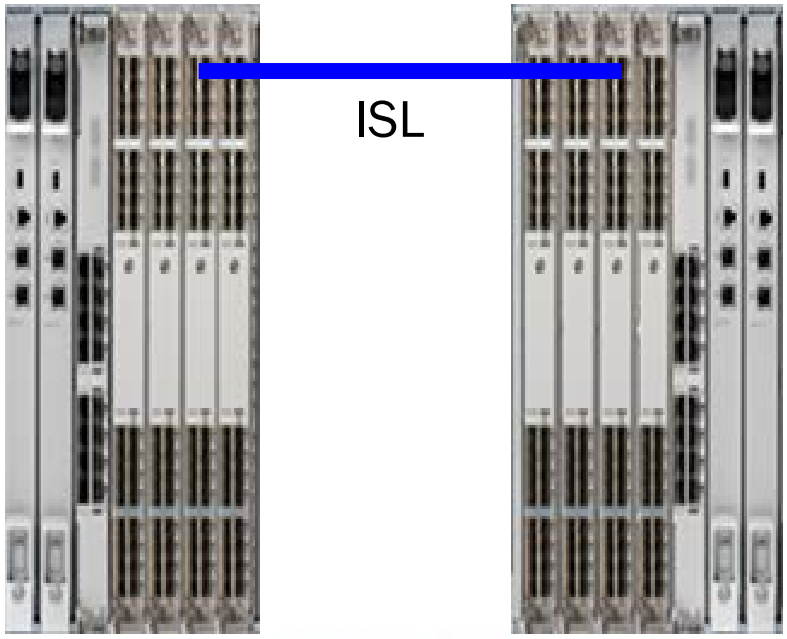
FCIP Tunnel

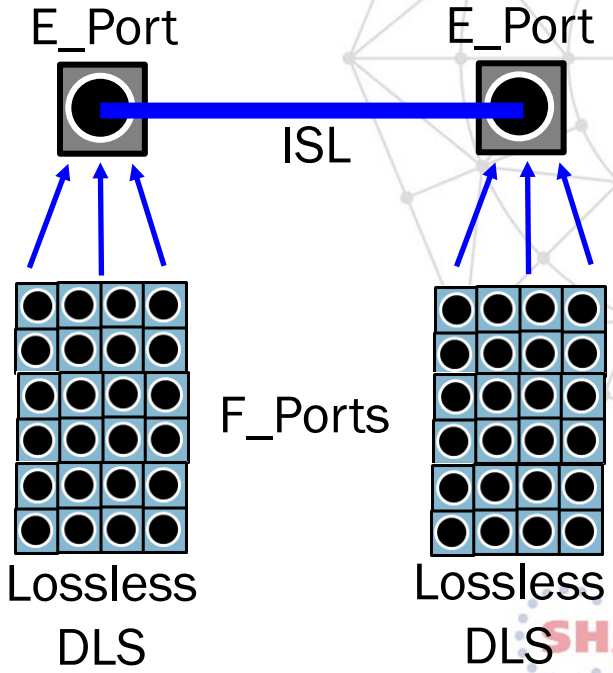


FC and FCIP Connectivity Overview

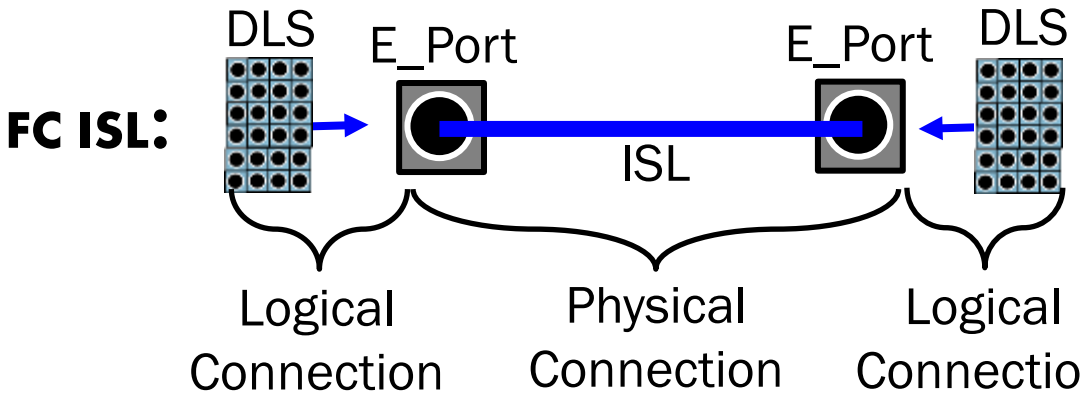
- Fibre Channel Inter-Switch Links (ISLs) and FCIP Tunnels both provide the capability to connect switching devices together, across distance, but do it in completely different ways.

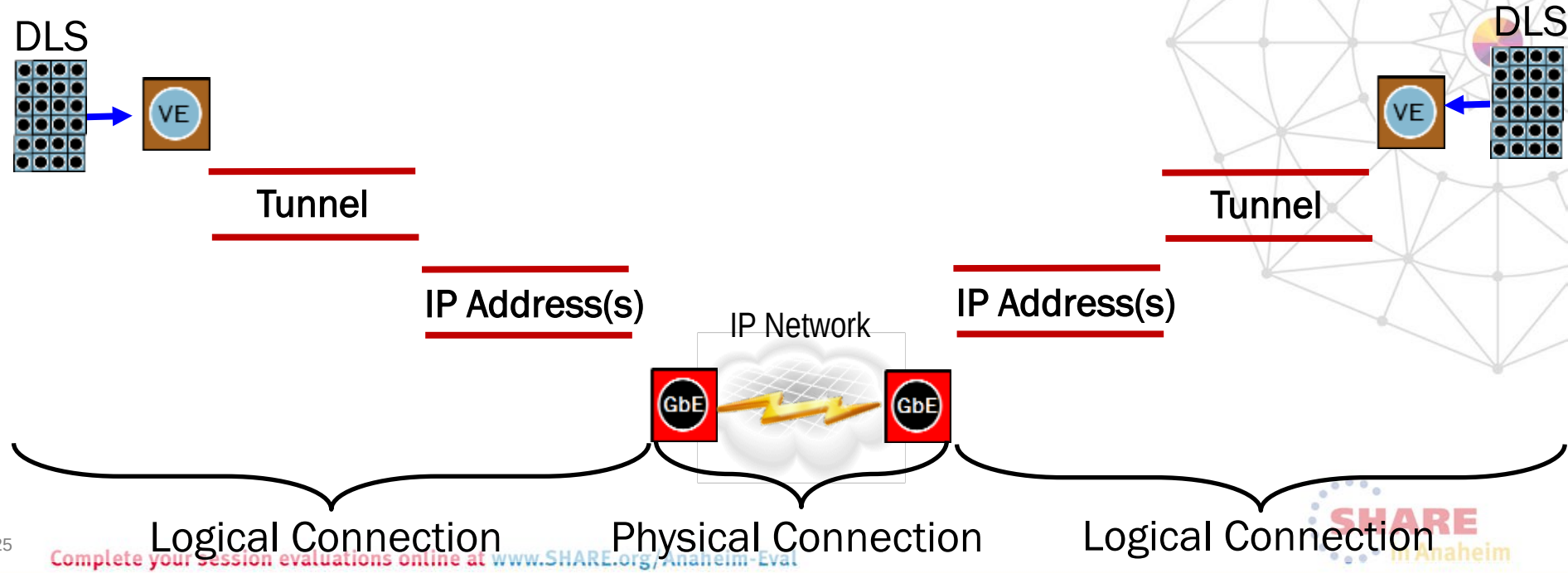
- FC ISL is a straight forward mechanism. An ISL is the physical link joining two Fibre Channel switches through Expansion ports (E_ports).



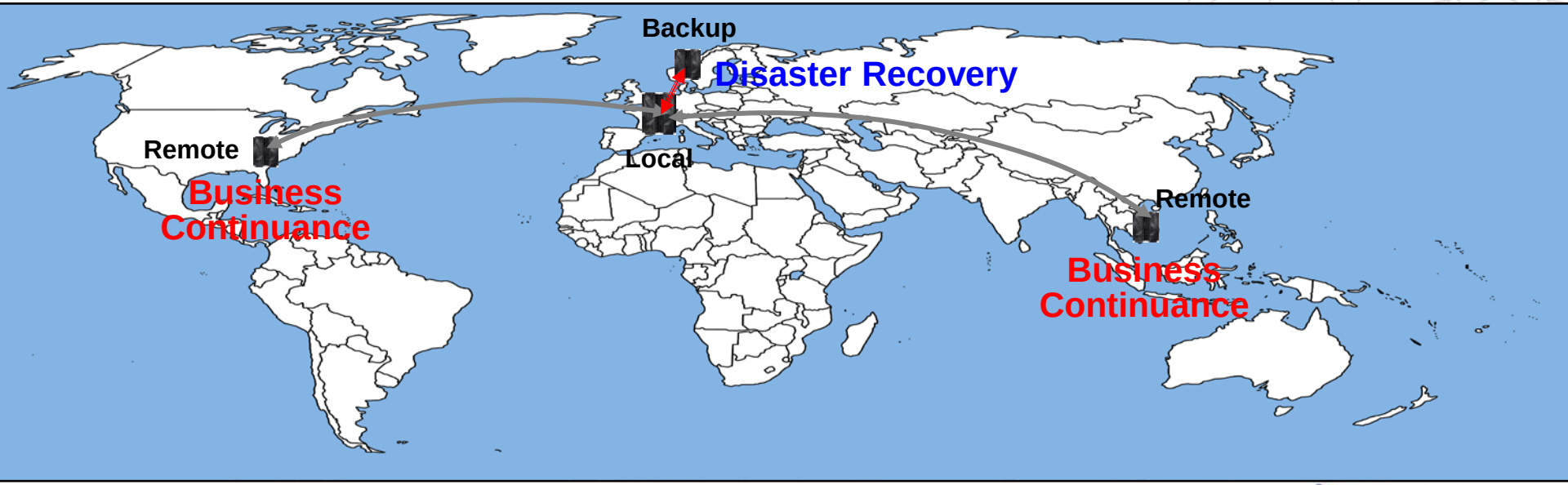


Components of FC and FCIP Connectivity





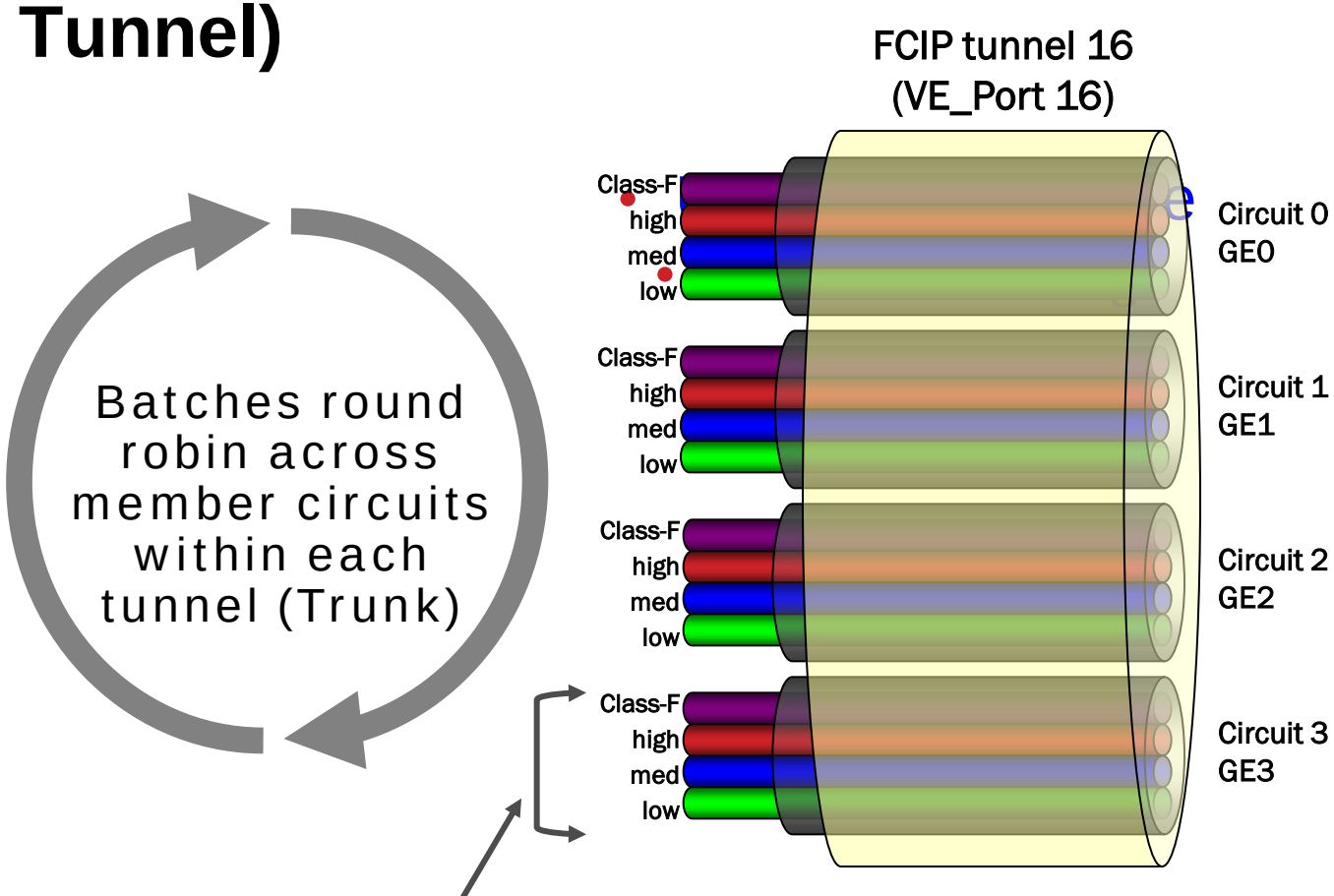
FCIP trunking, metrics/failover, and lossless link loss



FCIP Trunking

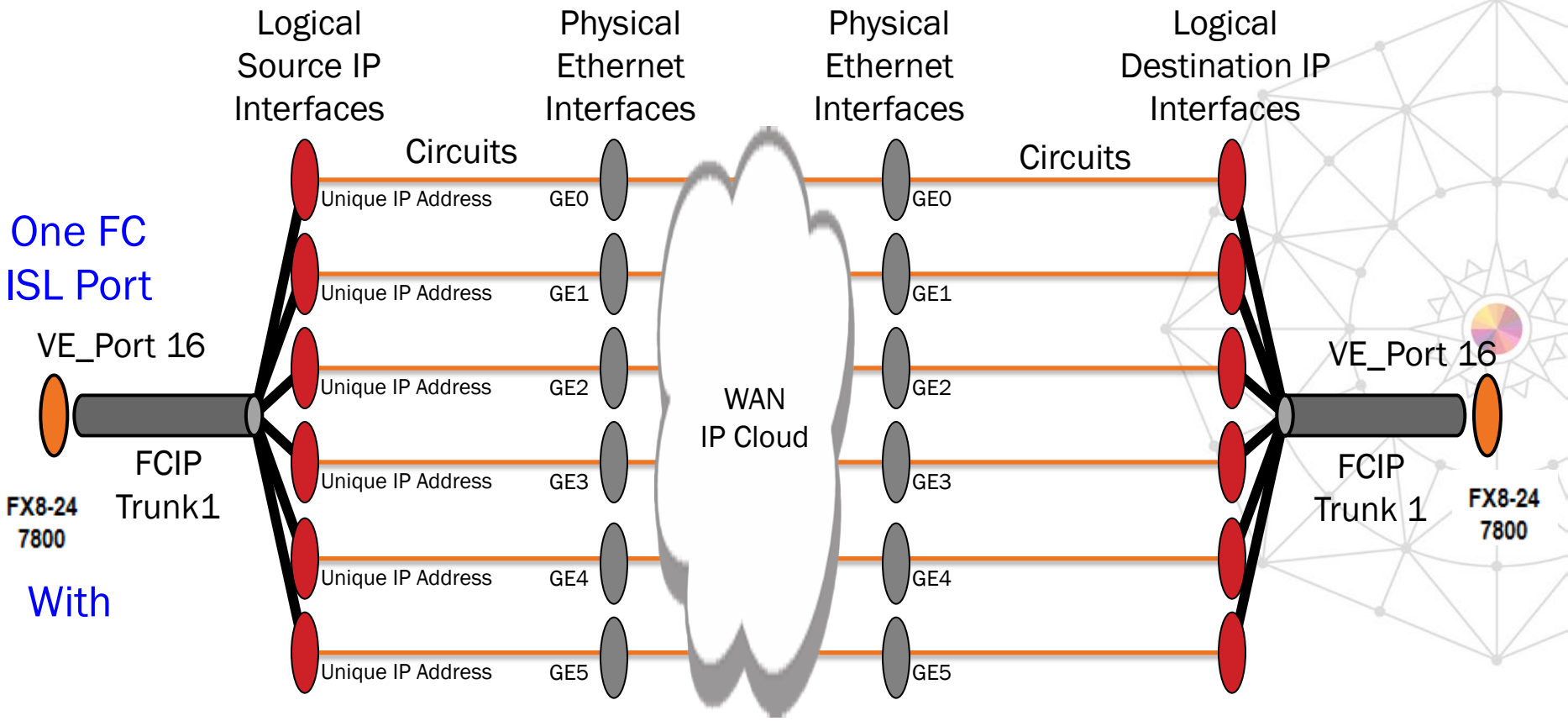
- FCIP Trunking is an FCIP Tunnel with more than 1 circuit
  - Also known as a Link Aggregation Group (LAG) or port channel
- FCIP Trunking provides:
  - **Single logical ISL** in routing table as a single link, ULP sees a single link
  - **Bandwidth Aggregation** of each circuit
  - **Load Balancing** per batch across the available circuits
  - **Failover** to remaining circuits when a circuit is lost
  - **Lossless Link Loss** (LLL)
    - Data in-flight is **not** lost when a link goes down, it will be retransmitted
  - **In-Order-Delivery** (IOD) Does not require switch "IOD" to be enabled
    - Data in-flight will be delivered in the correct order, even after a data loss in-flight
- Works with both FICON and FC
  - Supports FastWrite, OSTP, and FICON emulation over **multiple** circuits
- FCIP Trunking is a proven technology
  - Leveraged from widely deployed McDATA/CNT technology

FCIP Trunking – (e.g. 4 Circuits within 1 Tunnel)



VE_Port to VE_Port (Dedicated Ethernet Ports)

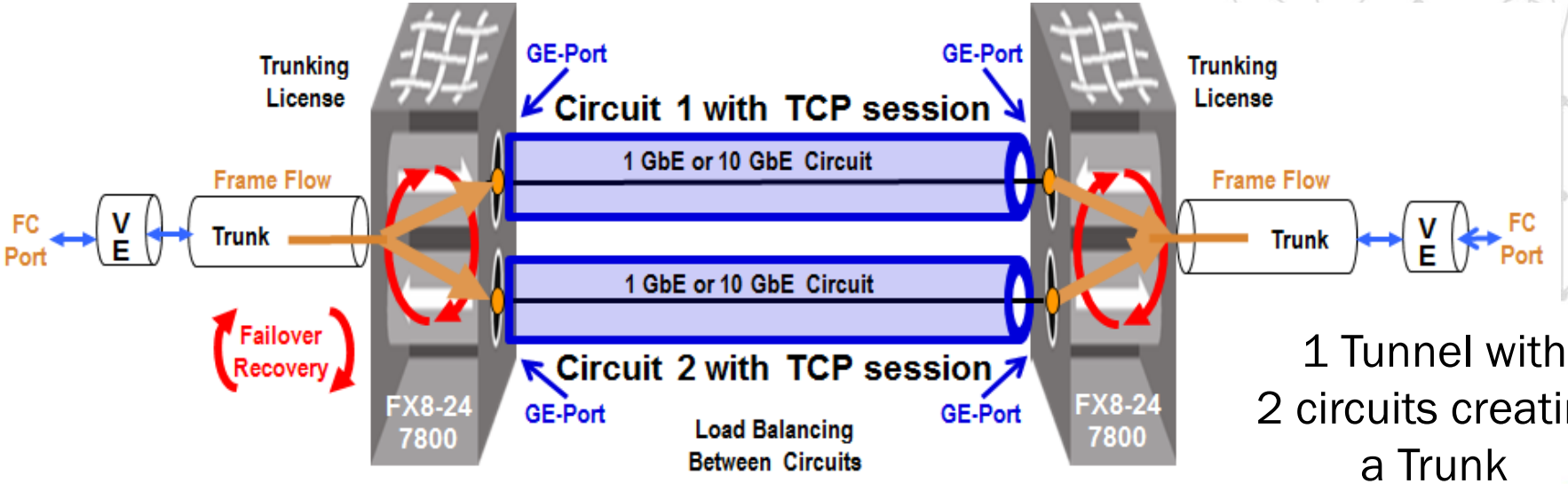
VE_Port ⇨ FCIP Trunk ⇨ IP Interface ⇨ Circuit ⇨ Ethernet Interface



- FCIP Trunks (multiple circuits) or Tunnels (single circuit) are logical entities
- IP interfaces are logical entities
- Circuits and Ethernet interfaces are physical entities

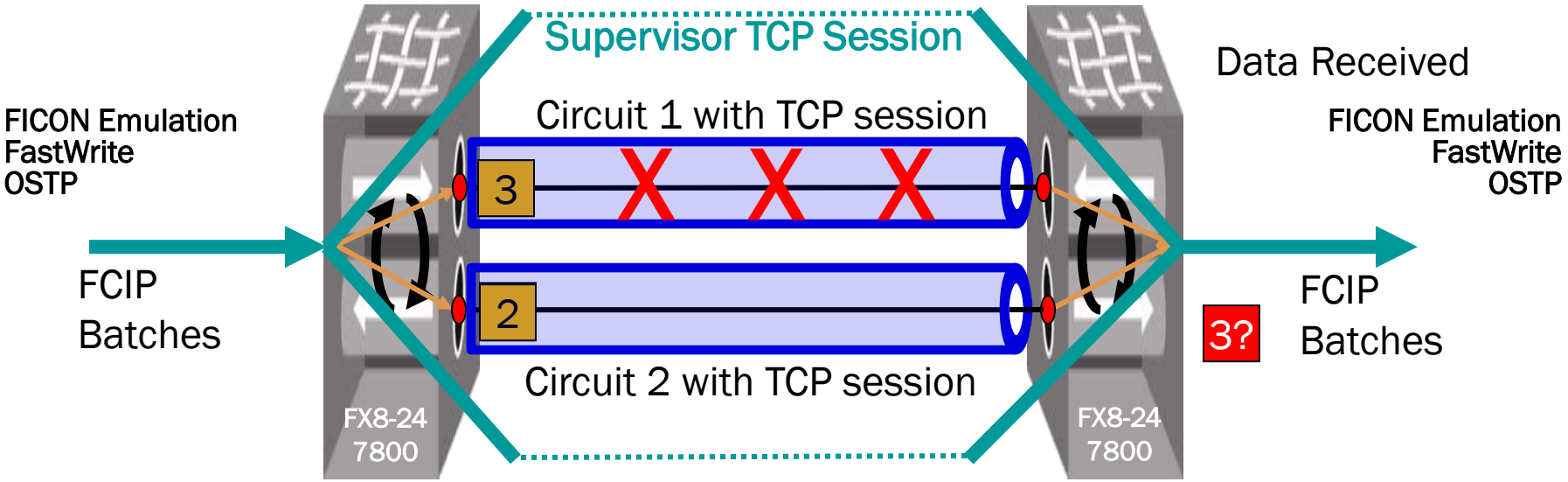
Using FCIP Trunking

- Purchase/Install the optional FCIP Trunking licensed feature
- Will enable the creation of logical high-bandwidth FCIP tunnels (aka “FCIP Trunks”) composed of multiple circuits, and spanning multiple physical ports:
  - Up to 20 FCIP tunnels are supported on the Brocade FX8-24
  - Up to eight FCIP tunnels are supported on the Brocade 7800
- Traffic within an FCIP Trunk will be balanced across all FCIP Circuits (up to 6 @ 1GbE and up to 10 @ 10GbE) to optimize bandwidth and performance.



1 Tunnel with 2 circuits creating a Trunk

FCIP Trunks also overcome physical link failures
L3 Lossless Link Loss (LLL) & I/O Load Balancing



Supervisor TCP Session

- FCIP Trunk appears as a single logical ISL
- Encapsulates each of the FCIP Circuits' TCP sessions within an FCIP Trunk
- Traffic within an FCIP Trunk is balanced across all FCIP Circuits to optimize bandwidth and performance. as well as FICON emulation
- FCIP Trunk will retransmit lost frames when there is a circuit failure/loss
  - For operational links, the TCP sessions within the circuit handle loss
- Ensures FC frames are delivered in order which prevents IFCCs from occurring
- Supports FCP FastWrite and OSTP as well as FICON emulation

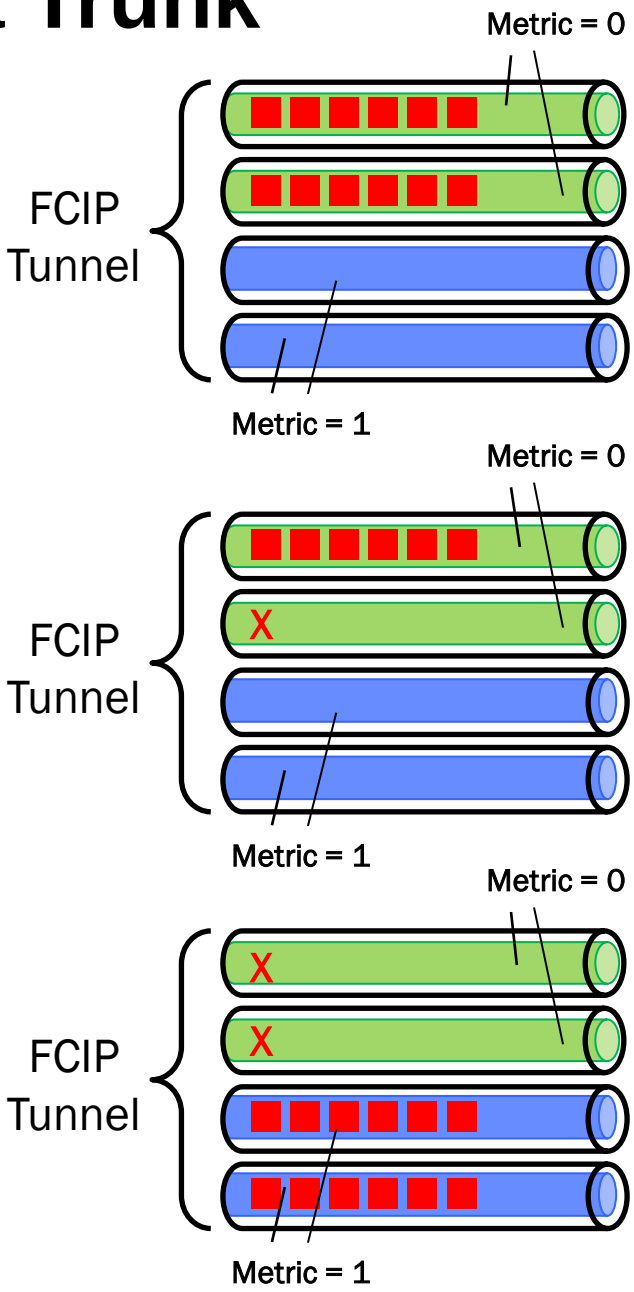
FCIP Trunking

FCIP Circuit Keep Alive Timers[1]

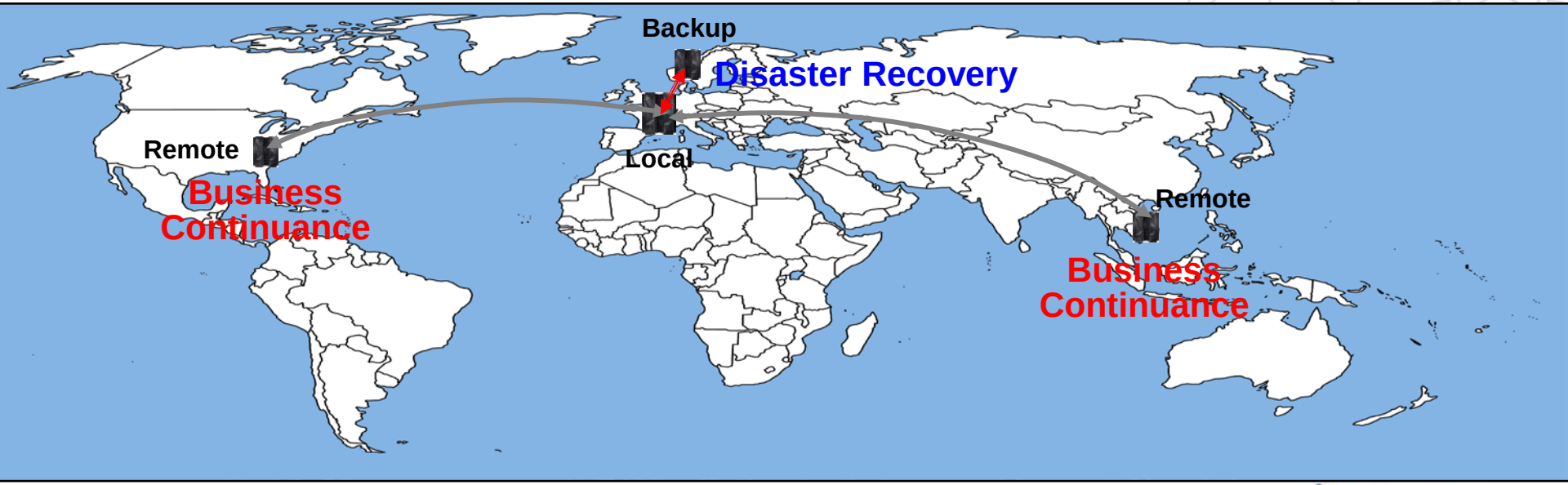
- The FCIP Circuit Keep Alive timeout has a FOS default value of 10,000ms (10 seconds)
- For FICON the Keep Alive timeout value should only be 1,000ms (1 second)
  - Local and remote Keep Alive values need to match or the tunnel uses the lowest value
  - Will need to modify the FOS default Keep Alive Timer value to support FICON
- 1 sec is the maximum supported for FICON
  - FICON has strict timing requirements
  - 1 second KATOV will work well for all circuits
- Non-FICON circuits default to keepalives of 10 sec
  - Best practice is to set all keepalives to 1 sec
  - If the user knows that their IP network has congestion and deep buffers then the keep alive may need to be longer than 1 sec
    - If a keepalive does not arrive within 1/5th of the value, it may cause link flapping

Controlling Traffic flow in a Trunk
Path Costing Technique

- All circuits have a metric of 0 or 1
  - Purpose is to control which circuit should be primarily utilized for I/O traffic[1]
- Circuits of the same VE_Port can have a metric of 0 or 1 – 0 is a preferred circuit
- Circuits metrics
  - All traffic goes through metric 0 circuits
  - No traffic goes through metric 1 circuits until all metric 0 circuits are offline
- Lossless Link Loss
  - When the last metric 0 circuit goes offline, data lost inflight will be retransmitted over metric 1 circuits
- Very useful in ring topologies to choose which ring to traverse

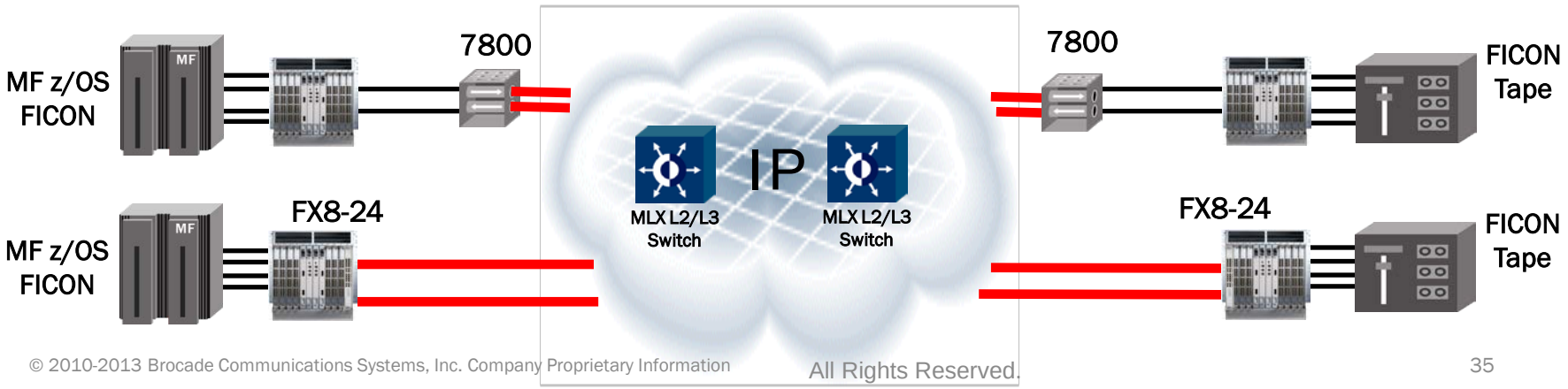


FICON protocol emulation: improved long distance performance



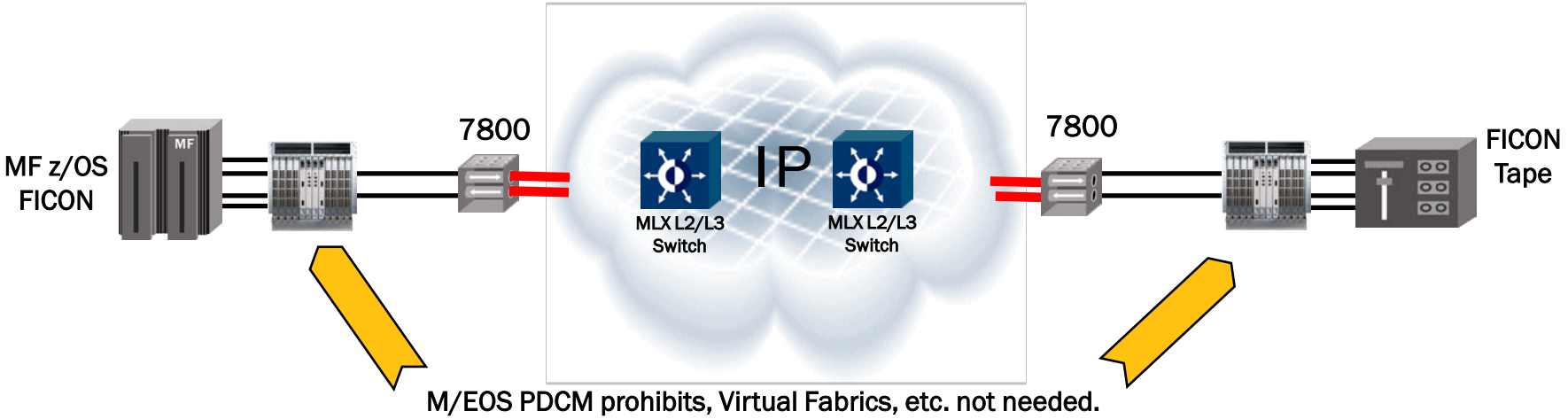
FCIP FICON Connectivity Between Data Centers
FICON Shuttle Mode – just a typical ISL link

- FCIP with or without Trunking:
  - In shuttle mode, the FCIP long distance link is treated as any other ISL link
- All types of data streams can run concurrently and bi-directionally on the same ISL port in shuttle mode – it just provides connectivity
- It does provide adequate performance out to ~300 Km
  - Extends FICON distance from its native FC 100km maximum range
  - Performance is limited to the FICON and WAN throughput capacities
- Use shuttle mode when there is no benefit from using Emulation Mode



FCIP FICON Connectivity Between Data Centers
FICON Shuttle Mode – considerations

- Multiple device types can be extended over the same FICON ports
  - Tape and Storage Array
  - Uni or Bi-directional data traffic
  - Client can utilize the Optica Technologies PRIZM converter for remote ESCON
- Multiple FCIP ISL's can be used between FICON directors
- No special pathing considerations when using shuttle mode FCIP
  - Traffic Isolation Zones can be utilized on these long distance ISL links
- BUT – z/OS Global Mirror (XRC) extension is NOT supported in this mode
  - zGM XRC needs performance and distance beyond what shuttle mode offers



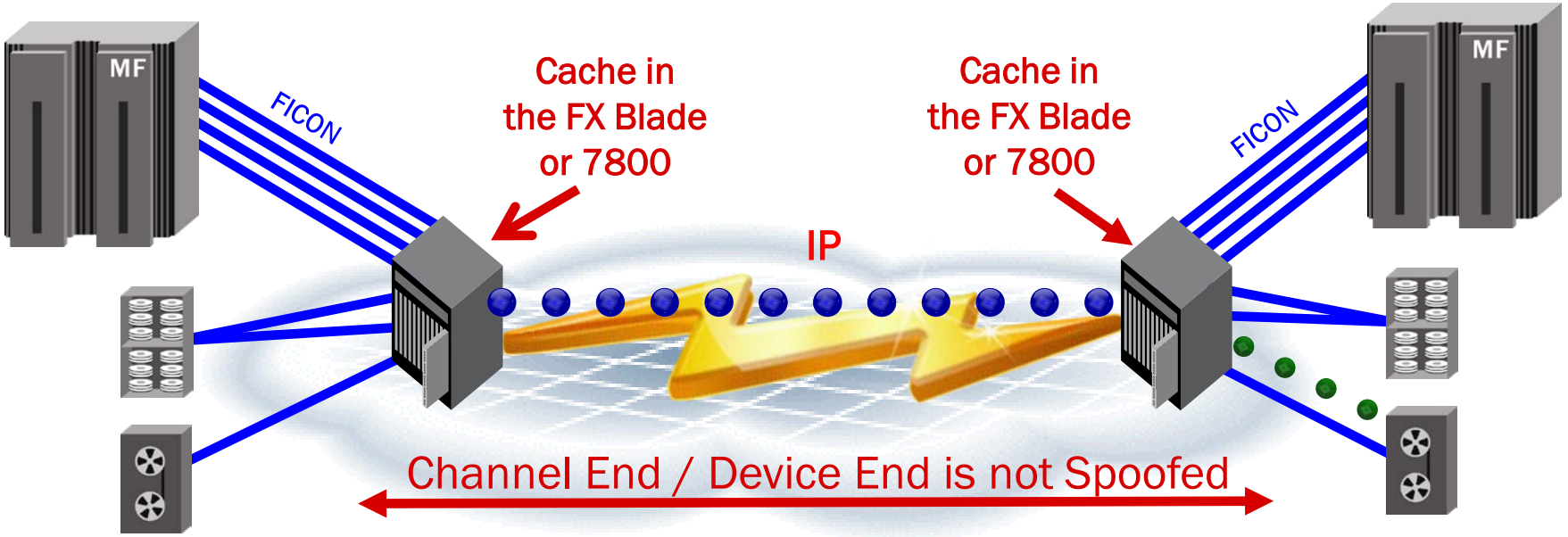
Brocade Innovation for FICON Extension
FICON Advanced Accelerator for FICON

- A licensed function of an FX8-24 blade and/or 7800 extension switch
- Conserves WAN bandwidth, reducing costs
- Provides exceptional FICON read and write performance over distance
- Enables improved disaster recovery and data protection, supporting:
  - FICON Read and Write Tape Pipelining
  - FICON Pipelining for Teradata
  - FICON Emulation for IBM z/OS Global Mirror (formerly XRC)
- Faster backups, faster recoveries over distance
- Flexibility to place FICON disk and tape where needed, regardless of location

Protocol Optimization Consideration

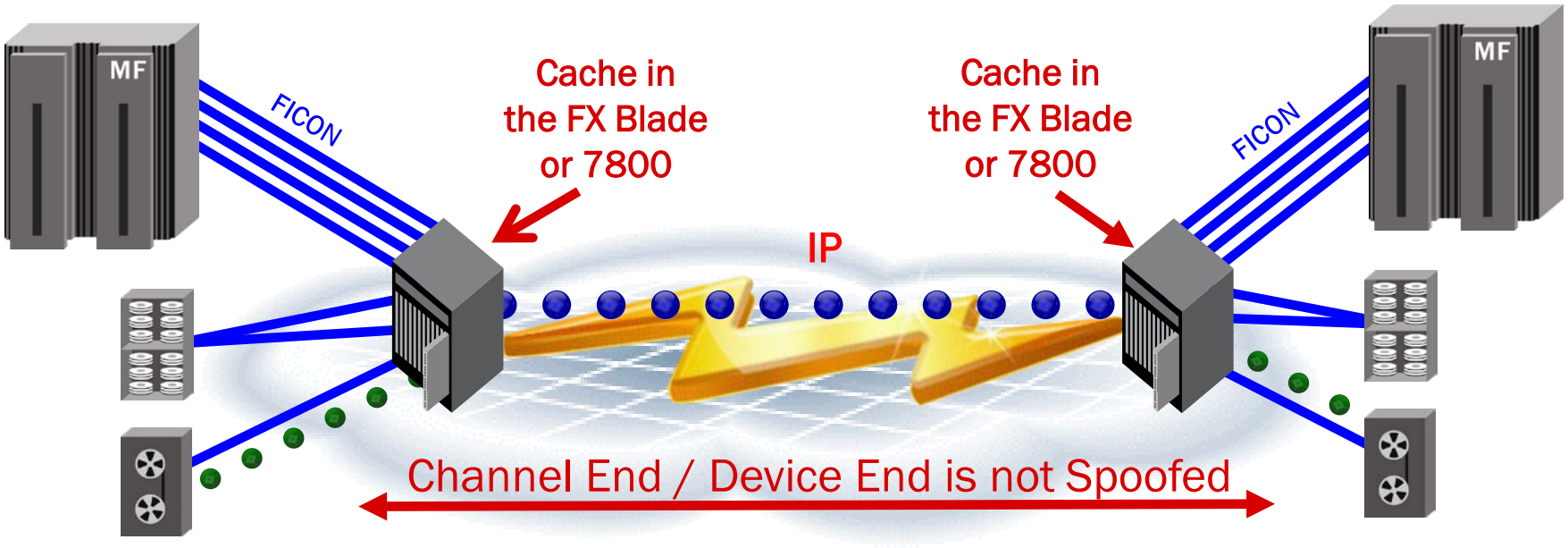
- Mainframe users rely upon z/OS services such as path group to maintain load balancing and to provide a "stateful" link environment[1]
- FCIP Emulation is outside the bounds of IOS and therefore the extension hardware is tasked with maintaining a stateful environment from a transmitter to a receiver in FCIP when emulation is in use
- In order to keep that responsibility as simple as possible, only a single deterministic path is allowed to be configured for emulated data
- Protocol optimization for emulation is based in a VE_Port
  - A deterministic path to the VE_Port is required for both outbound and return traffic. Possible methods:
    - Single physical path from end-to-end
    - VF Logical Switches with one VE_Port per LS
    - Traffic Isolation Zones (TIZ)

Brocade Write Tape Pipelining for FICON
FICON Based Tape and Virtual Tape Extension



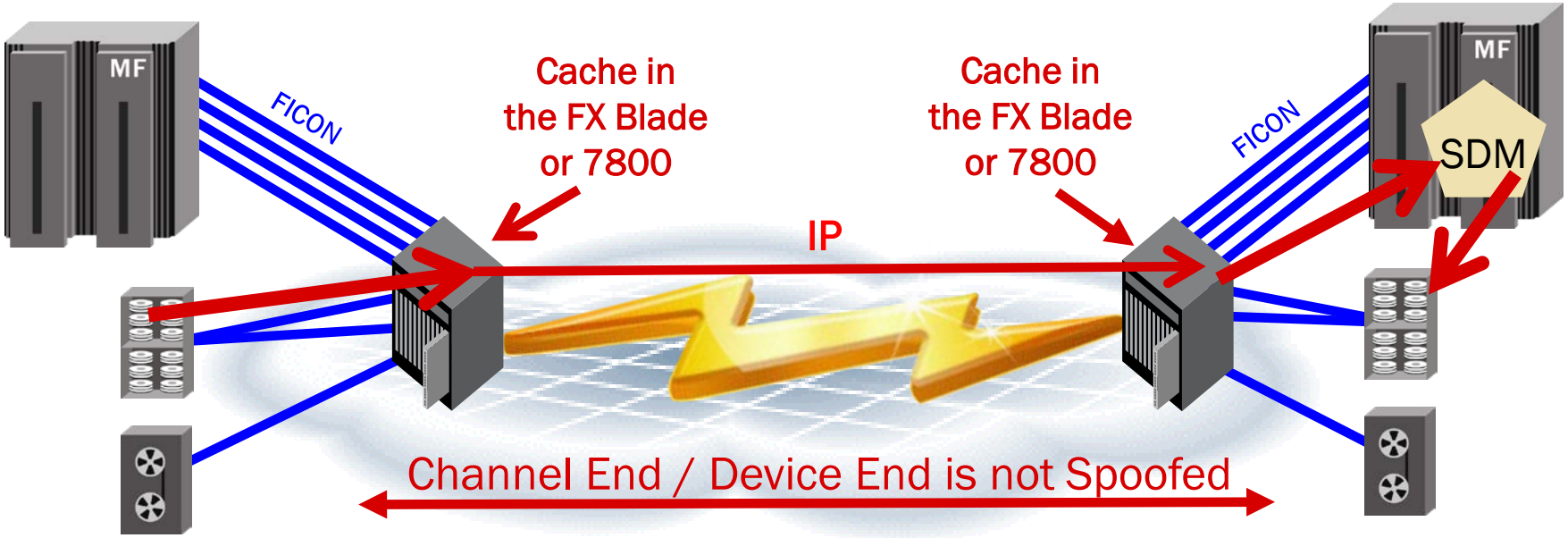
- Tape Write Pipelining basically uses the cache in the remote extension device (7800 or FX8-24) to respond to its attached tape devices as if the data were being generated locally
- Tape Write Pipelining Process:
  - Pre-acknowledges write sequences received from the channel
  - Write chains sent to remote side for actual writes to the tape storage CU (control unit)
  - Simultaneous outstanding Write Command Acknowledgements
- Write Pipelining mode only works with typical write channel programs – nothing exotic
- It there are other tape write commands which are non-compliant they will cause pipelining to gracefully exit emulation sequences.

Brocade Read Tape Pipelining for FICON
FICON Based Tape and Virtual Tape Extension



- Tape Read Pipelining basically uses the cache in the remote extension device (7800 or FX8-24) to respond to its attached tape devices as if the data were being generated locally – provides industry leading performance for read operations over
- Tape Read Pipelining
  - Discovers the mode of a Read Block or a Read Channel program
  - Pre-reads the tape data and sends it to host side for presentation via the cache
  - Host channel is released and all of the read responses are presented to the channel when requested

IBM z/OS Global Mirror (formerly XRC) Emulation
FICON Based Storage Array Replication



- IBM z/OS Global Mirror (formerly XRC) data replication is performed by pulling information from a primary DASD via System Data Mover (SDM) -- remote read operation
- Distance (latency) impacts read performance
- When FICON emulation for XRC is enabled, our extension devices automatically go into emulation mode to provide a significant performance improvement for DASD replication
- Emulates XRC RRS (Read Record Set) sequences, accelerating data flows to the host, and queuing at the channel for SDM
- Maintains integrity of command and acknowledgement sequences

FCIP FICON Connectivity Between Data Centers
FICON Emulation Mode – Advanced FICON Accelerator

- Auto-detection of Teradata, XRC (Storage Array) and Tape devices for emulation

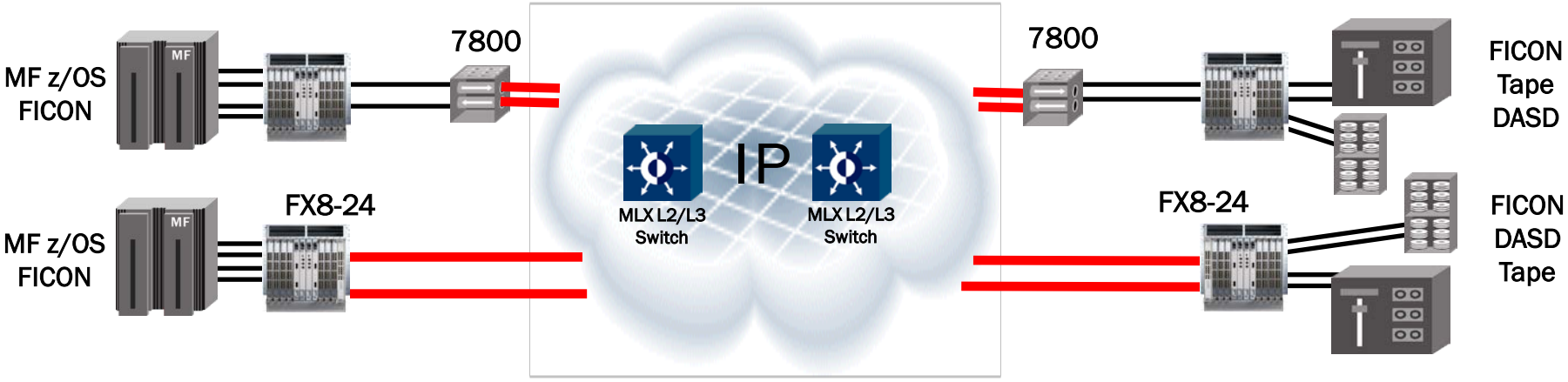
- Control block structures are dynamically allocated so that the devices can be emulated as they are discovered
  - z/OS Global Mirror (XRC) Storage Array
  - Tape (i.e. VTS/VSM, as well as standalone FICON tape)
  - Teradata Warehouse Storage Array data

- On FCIP links, automatically switch between Emulation Mode and Shuttle/Tunnel Mode based on the operation being performed
  - Device specific intelligence

FCIP FICON Connectivity Between Data Centers
FICON Emulation Mode – Considerations

- Commands, data, and acknowledgments all need to use the same FICON path in both switching devices for each end of the connection
  - Cannot traverse one ISL path down and a different ISL path back
  - Multi-pathing to Tape/VTS/VSM/XRC/DASD is NOT supported
  - These are critical factors to ensure emulated devices work properly

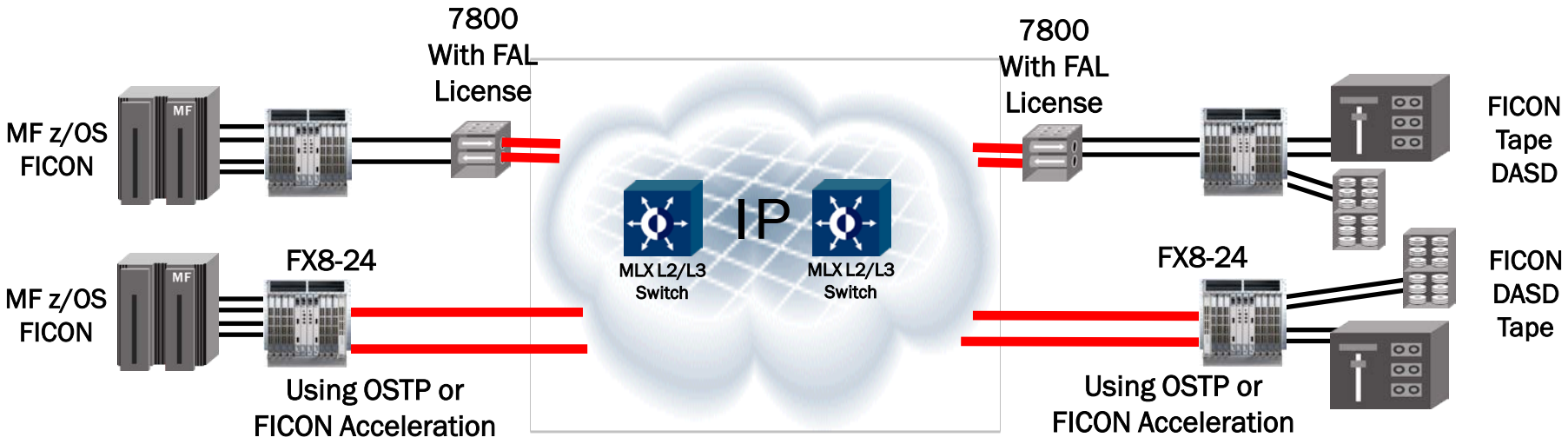
- Multiple ISL's can be used between cascaded FICON directors:
  - But pathing needs to be configured so that a FICON port on the FICON switching device always uses the same ISL down and back
    - Accomplish this through Traffic Isolation Zones, Virtual Fabrics, etc.



FCIP FICON Connectivity Between Data Centers
Considerations with FICON Emulation / FCP Acceleration

- Multiple FCIP tunnels are not supported between pairs of 7800 switches or FX8-24 blades with any of the FICON or FCP emulation/acceleration features

- These features require deterministic FC Frame routing between all initiators and devices over multiple tunnels:
  - Non-controlled, parallel (equal-cost) tunnels are not supported between the switch pairs when emulation is enabled
  - **Must use TI Zones or Virtual Fabric configurations** when routing these emulated or accelerated SID/DID pairs



FCIP Compression and Security
Should always use IPsec and Compression with FCIP

Can be used independently

IPSEC (this is encryption)

- Internet Protocol Security (IPsec) is a protocol for securing Protocol (IP) communications by authenticating each IP packet of a communication session:
  - There is no license and no cost for IPsec on our extension devices
  - IPsec adds only 5 µs (microseconds) of latency to each FCIP frame
  - IPsec is not a performance problem since it operates at line rate
  - FX8-24 has IPsec on 1 of the 2 FCIP engines while the new FX8-24E (FOS 7.1.0c) can do IPsec on both FCIP engines.

Hardware Compression (can be used with or independent of IPsec)

- Advanced Compression architecture provides flexibility to optimize compression ratios and maximize throughput:
  - Capacity of our compression engine to maintain data flow at line rate
  - Optimization of the Maximum Transmission Unit (MTU) of datagrams
  - 7800/FX8-24 compress data and batch multiple FC frames per TCP segment
    - Three different compression modes to choose from

Summary and Conclusions

- FCIP provides a robust DR/BC network solution for a variety of distances.
- FCIP is ideal for both open systems, as well as System z environments
- FCIP takes advantage of the TCP protocol for error recovery and data integrity.
- FCIP protocol emulation technology provides high performance at very long (global) distances

Questions?