SAN Design and Best Practices

Design Guide

Broadcom

53-1004781-06
May 10, 2024

Broadcom reserves the right to make changes without further notice to any products or data herein to improve reliability, function, or design. Information furnished by Broadcom is believed to be accurate and reliable. However, Broadcom does not assume any liability arising out of the application or use of this information, nor the application or use of any product or circuit described herein, neither does it convey any license under its patent rights nor the rights of others.

The product described by this document may contain open source software covered by the GNU General Public License or other open source license agreements. To find out which open source software is included in Brocade products or to view the licensing terms applicable to the open source software, please download the open source attribution disclosure document in the Broadcom Support Portal. If you do not have a support account or are unable to log in, please contact your support provider for this information.

Table of Contents

Chapter 1: Preface

1.1 Introduction

The storage landscape continues to modernize, and we must make informed decisions to design an exemplary Fibre Channel architecture. This document is a high-level storage area networking (SAN) design and best practice guide for Brocade products and features, focusing on Fibre Channel SAN design. Topics include the early planning phase, understanding possible operational challenges, and monitoring and improving an existing SAN infrastructure.

The guidelines in this document do not apply to every environment, but they will help guide you through decisions for a successful SAN design. Contact your Broadcom representative or refer to the documents in Appendix D for details about the hardware and software products.

NOTE: This is a *living* document that is updated frequently. Check www.broadcom.com for the latest updates to this document and to other best practice documents.

1.2 Audience and Scope

This guide is for IT architects who are directly or indirectly responsible for SAN design based on Brocade® Fibre Channel platforms. It describes the challenges faced by SAN designers in greenfield and legacy environments. While not intended as a definitive design document, this guide introduces concepts and guidelines to help avoid potential issues resulting from poor design.

This document describes best practice guidelines in the following areas:

- Modernizing the storage landscape
- Architecting a SAN
- SAN topologies
- Data flows
- Traffic Optimizer
- Fabric Performance Impact Notification (FPIN)
- Predeployment infrastructure testing
- Device connections
- Scalability and performance
- Supportability
- Monitoring
- Troubleshooting
- FC Routing
- Intelligent services
- NPIV
- Access Gateway
- Workloads
- SAN management
- Security
- Automation

NOTE: A solid understanding of SAN concepts and Brocade Fibre Channel technology is assumed. Please see Appendix D or recommended additional publications.

1.3 Approach

Although some advanced features and specialized SAN applications are discussed, these topics are covered in greater detail in separate documents. The primary objective of this guide is to provide a solid foundation to facilitate successful SAN designs—designs that effectively meet current and future requirements. This document addresses basic administration and maintenance, including capabilities to identify early warning signs for end-device (initiator or target) latency, which can cause congestion in the SAN fabric. However, you should consult product documentation and documents in Appendix D or more details. Comprehensive discussions of SAN fabric administration, storage network cabling, and Fibre Channel security best practices are covered in separate documents.

1.4 Overview

Although Brocade SAN fabrics are plug-and-play and can properly function if left in a default state, Fibre Channel networks benefit from a well-thought-out design and deployment strategy. Your SAN topology should follow best practice guidelines to provide reliable and efficient data delivery. The best practice guidelines in this guide are based on SAN industry standards, tremendous experience, and considerations specific to Broadcom® products.

This document does not consider physical environment factors such as power, cooling, and rack layout. Instead, the focus is on network connectivity edge devices to the fabric, inter-switch links (ISLs), and software configurations.

NOTE: The scope of this document is switch-centric and does not discuss HBA, storage, end-device setup, configuration, and maintenance. Some fabric monitoring, management, diagnostics, cabling, and migrations are covered, but if you want full details, please refer to other appropriate documents.

Chapter 2: Storage Landscape

2.1 The Storage Landscape

In the IT infrastructure world, storage is critical; it is where data lives, secure copies exist, and it is the foundation of application performance. No matter how many CPU cores or how much memory a server might have, every server waits for data.

Consequently, the scope of this environment includes early disk drives, tape for securely and cost-effectively backing up the data, and software implementations that provide access, performance, and security. Furthermore, the storage administrator's responsibilities include securing copies of the data through RAID configurations or site-to-site replication solutions. The mantra of storage admins is “a single copy of any data set is a single point of failure waiting for a disaster to occur.” Data loss is never an acceptable option from the application point of view.

2.2 Tipping Point—The All-Flash Data Center

Over the years, the state of the storage environments in IT has changed dramatically. A quick review of the changes takes you from the early tape systems through the evolution of the hard disk drive (HDD) into developing RAID systems and enterprise arrays. One of the things that had traditionally been true was that storage, based on HDD building blocks, evolved slowly. Changing from 5400 RPM disk drives to 7200 RPM disk drives as a performance element (more data under the head per second) took ten years to fully populate data centers. Other developments included the density of the magnetic signature on the drive platter and the number of platters and heads per drive. This retrospective is only helpful by denoting that the storage environment in IT did not progress as rapidly as, say, CPU development or memory performance and capacity. Those developments were in silicon, and drive development was mechanical. As a result, Moore’s Law applied to CPU and memory but not to storage. The nature of storage has begun to change with the advent of solid-state drives (SSDs).

Initially, the progress was moderate. In a brilliant market-enabling move, the drive vendors made the SSD platform the same shape/canister as existing HDDs with the same SCSI, SAS, and SATA connectors, which meant *plug compatibility* on the back end of the array for the new technology. However, early on, the enterprise array controllers and, in the case of embedded disk drives in servers, the OS driver stack did not take advantage of the change in performance and other drive characteristics. The OS stack not taking advantage of the new technology was part of why the early *hybrid arrays*, which used a mix of traditional HDD and SSD drives on the back end, were less performant than many storage administrators had expected. Not meeting expectations impacted the adoption rate, and the IT organization did not experience as much of an issue with existing storage networks as expected. For over 40 years in IT, we have been moving bottlenecks in CPU performance, memory speed/scale, storage capacity/performance, and network speeds. Removing one bottleneck simply lets you find the next one, not unlike how widening one segment of a major highway pushes the traffic backup to the next narrow section of the highway. The result was that many customers felt that the performance gain versus the technology cost was only fit for their very highest-demand applications.

The cost per terabyte became more enticing with the advent of the all-flash array environment and inline features, such as compression, encryption, and deduplication. Additionally, the newer enterprise array controllers were designed for all-flash performance characteristics and significantly increased both input/output operations per second (IOPS) and latency. Added to that was the storage density, which allowed them to collapse multiple racks of HDD platforms into a partial rack of SSD with the benefits of power and cooling reduction. What was the consequence? There is a much more rapid adoption rate of all-flash arrays, which are currently more than 70% of the shipping environment.

That technology shift leads to changing demands on the design of storage area networks, which is true regardless of the technology used. If the expectation is to utilize the capacity and performance of these platforms, then serious consideration has to be given to the design.

A dedicated storage network infrastructure that provides lossless, low-latency, deterministic, scalable, and performant storage services to the applications becomes critical. Storage admins will talk about *fan-in* or *fan-out* ratios for storage platforms, which are the number of servers and applications in the network using a particular array or array port for their storage access.

Depending upon the types of applications and their performance needs, that ratio might range anywhere from low single digits to 40 to 50 servers (hundreds of virtual machines). As with any provisioning scenario, the storage admin is dealing with projections of how much capacity and performance any server or application will use. But application performance is variable; time of day, week, month, and seasonal or event-driven events cause spikes or drops in application demand.

Another consideration is that the entire application base does not refresh simultaneously. The typical scenario is that multiple generations of performance will simultaneously exist in the environment. The availability of service windows drives this to re-platform existing environments to new servers and storage. Some legacy applications might not have an environment that runs a current operating system or application version. One might have ten-year-old or older operating systems connected with a HBA with two or more older generations of technology behind it. How, then, do you balance that still critical application against the needs and performance of the newer machines?

The answer is a combination of topology, balanced provisioning, granular monitoring, and automated mitigation.

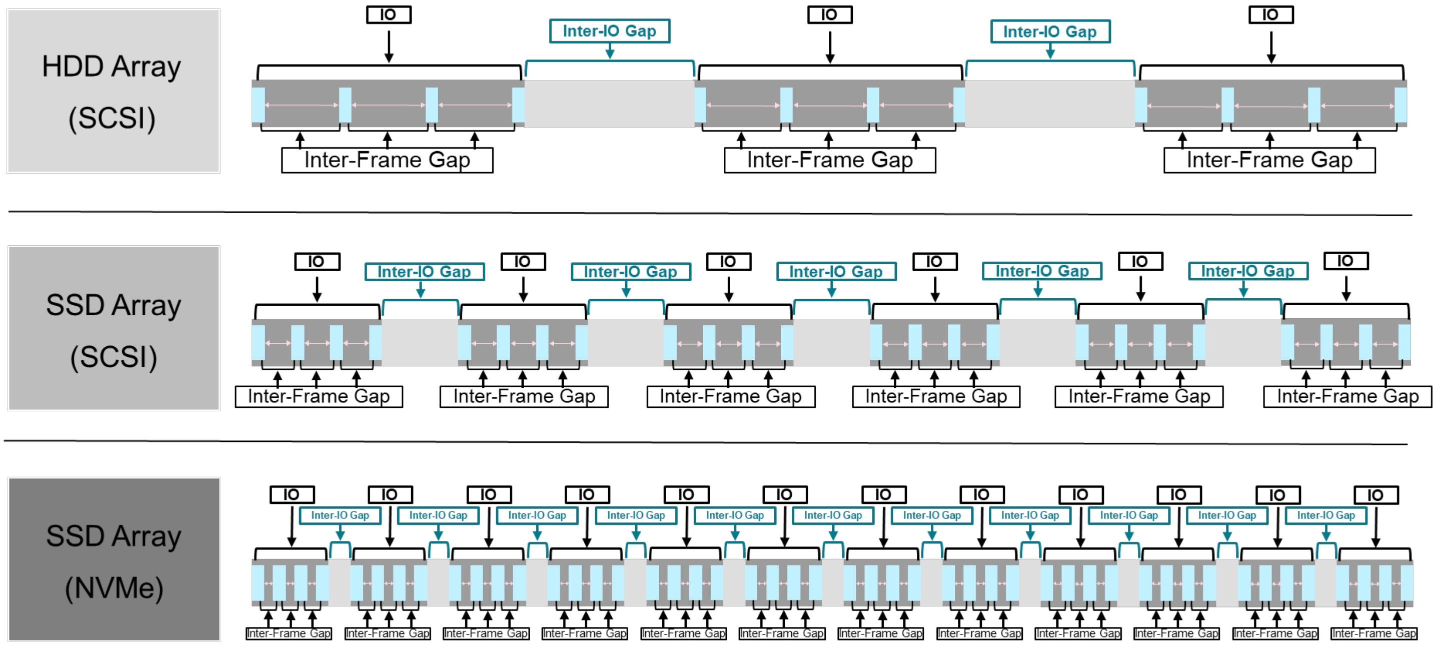
The most flexible configuration is a core-edge topology. Such an architecture allows significant scaling while keeping the number of *hops* low, the number of times the data transfers from one platform to another. The locality of storage connectivity for high-performance applications is a consideration that drives some storage admins to place storage ports on the same blade, switch or port group as the application server. This design, however, does impact the flexibility of IT to move the application from one server platform to another (not a trivial consideration in a highly virtualized environment where hypervisor platforms might frequently migrate applications between server platforms).

Another alternative topology is a full-mesh design; every switch has direct ISL to every other switch in the fabric. Full-mesh is problematic for environments with many switches since it consumes valuable ports for ISLs that otherwise would be used to connect servers and storage. Director platforms have inter-chassis links (ICLs), allowing exceptional bandwidth and scale between chassis without consuming ports. Full-mesh ensures no end device is more than one hop away from any other end device.

From a performance perspective, it is essential to note that the advent of the all-flash data center also means that new storage technologies, performance-based, capacity-based, or both, arrive at 18- to 24-month intervals. Technology refresh does not imply the wholesale replacement of the existing platforms but rather that your storage network must be able to accommodate roughly two of these iterations per 4- to 5-year capital depreciation cycle. One advantage of a Fibre Channel SAN is the dual-redundant hardware and isolated nature of SAN architectures. A and B fabric architectures portend that no device defect, scheduled maintenance, accidental human event, or malicious activity will completely take storage connectivity offline. Keeping storage networking online allows for seamless technology refreshes, which applies to technology upgrades for the storage network elements and attached server and storage.

One of the additional changes required by the all-flash data center is improved monitoring, partly due to the reduction in latency, the criticality of data, and the high amount of data in-flight in modern SANs.

Figure 1: NVMe Implies Less Idle Time on the Network



As shown in Figure 1, the amount of idle time in the network continues to decrease. Consequently, the *event window* of a problem can be very brief, and traditional monitoring systems based on *sample rate* (inspecting perhaps one packet in 8000), while sufficient for modeling, might not provide the rapid root-cause analysis that the modern SAN requires. The scale of modern all-flash storage further exacerbates the situation. Specific platforms can scale above a petabyte (a petabyte [PB] is 1000 terabytes [TB]) of capacity within a mere two rack units. The consideration here is that such a platform could host between 6000 and 10,000 virtual machines or applications, and any problem or outage affecting that kind of footprint becomes intolerable. Within the SAN, high availability requires granular monitoring with self-optimizing and self-healing technology. Humans are no longer fast enough or responsive enough to address problems in an all-flash data center without first suffering an outage.

2.3 NVMe

Another consideration why storage networks must be reconsidered and re-architected is non-volatile memory express (NVMe). At the device level, there are some characteristics to be aware of:

- Density – Current NVMe devices have 8 to 10 times the density of DRAM.
- Latency – Current NVMe devices have a sub-20-microsecond latency.
- Bandwidth – Current NVMe devices consume 4 PCIe Gen 3 lanes (32G).
- Streamlined software – Current NVMe software has 13 required and 25 optional commands.

Why are these characteristics important? Because storage density continues to increase on a rough Moore’s Law schedule. The latency of devices continues to reduce and is significantly lower than HDD or traditional SSD devices. Network environments below 64G FC are potential choke points for fan-in and fan-out ratios supported by large-scale storage platforms. The language used to communicate with storage is changing for the first time in over three decades.

Taking advantage of new technology, especially its performance aspects, requires special attention to the storage network—legacy environments, whether Ethernet or Fibre Channel, will not take advantage of NVMe performance.

“Speed is the new currency of business” - Marc Benioff, CEO of Salesforce

Reducing application overhead with streamlined software stacks, scaling IOPS, and driving consolidation depend on infrastructure. An NVMe over Fibre Channel fabric is a production-ready NVMe environment.

Conversion will be slow, as it will take time for all servers and applications to migrate to NVMe from SCSI. With the proper design and implementation of a Fibre Channel SAN, NVMe and SCSI can run concurrently on the same HBA, FC switch, and storage. Potentially, applications can be migrated nondisruptively from SCSI to NVMe.

However, this new environment will need to be self-learning, self-optimizing, and self-healing simply because it will be too critical and performant to wait for human intervention to solve problems before they become disruptive.

Chapter 3: Architecting a SAN

The SAN planning process is similar to any project planning process, and it includes the following phases:

- Phase I: Gathering requirements
- Phase II: Developing technical specifications
- Phase III: Estimating project costs
- Phase IV: Analyzing return on investment (ROI) or total cost of ownership (TCO) (if necessary)
- Phase V: Creating a detailed SAN design and implementation plan

When selecting which criteria to meet, you should engage users, server and storage subject matter experts (SMEs), and other relevant experts to understand the role of the fabric. Since most SANs operate for a long time before they are renewed, consider future growth as SANs are complex to re-architect. Deploying new SANs or expanding existing ones to meet additional workloads in the fabrics requires a critical assessment of business and technology requirements. Proper focus on planning will ensure that the SAN, once deployed, meets all current and future business objectives, including availability, deployment simplicity, performance, future business growth, and cost. Tables in Appendix B are provided as a reference for documenting assets and metrics for SAN projects.

A critical aspect of successful implementation that is often overlooked is the ongoing management of the fabric. Identifying systems-level SMEs for all components that make up the SAN and adequate and up-to-date training on those components is critical for efficient design and operational management of the fabric.

When designing a new SAN or expanding an existing SAN, you should consider the following parameters:

- **Application Virtualization**
  - Which applications will run under a virtual machine (VM) environment?
  - How many VMs will run on a physical server?
  - Under what conditions will the VMs be migrated (business and nonbusiness hours; is additional CPU or memory needed to maintain response times)?
  - Is there a need for solid-state storage media to improve read response times?
- **Homogeneous/Heterogeneous Server and Storage Platforms**
  - Are blade servers or rack servers used?
  - Is auto-tiering in place?
  - Which Brocade Fabric OS® (FOS) versions are supported in a multivendor storage environment?
  - What is the planned refresh cycle of servers and storage platforms (2 years or 3 years)?
- **Scalability**
  - How many user ports are needed now?
  - How many devices will connect through an access gateway?
  - How many ISLs and Brocade UltraScale ICLs are required to minimize congestion in the fabric?
  - What distances for ISL and ICL connections need to be supported?
  - Does the fabric scale out at the edge of the core?
- **Backup and Disaster Tolerance**
  - Is there a centralized backup? (This determines the number of ISLs needed to minimize congestion at peak loads.)
  - What is the impact of backup on latency-sensitive applications?
  - Is the disaster solution based on long-distance metro FC ISLs or a FC over Internet Protocol (FCIP) solution?

- **Diagnostics and Manageability**
  - What is the primary management interface to the SAN (CLI, Brocade SANnav, or third-party tool)?
  - How often will Brocade FOS and SANnav be updated?
  - How is cable and optics integrity validated?
- **Investment Protection**
  - Is support needed for adding Gen 7 switches into a Gen 6 fabric?
  - Is support needed for storage technologies like NVMe over fabrics?
  - What device interoperability support is required?
  - Is interoperability required for other technologies such as UCS?

3.1 Operational Considerations

Even though Brocade fabrics scale in port density and performance, the design goal should ensure simplicity for the highest availability, most straightforward management, future expansion, and serviceability. Examples of this simplicity include using a two-tier core-edge topology, avoiding FC routing (FCR), Virtual Fabrics when not required, and enabling port monitoring parameters for critical applications.

NOTE: Refer to the *Brocade SAN Scalability Guidelines* for currently tested and supported scalability limits. Any requirements beyond the tested scalability limits should be pretested in a non-production environment. Additionally, monitor system resources like CPU and memory utilization to minimize fabric anomalies.

3.2 Be the Pilot

Whether building a new SAN or connecting to an existing one, pre-staging and validating a fabric or application before putting it into production ensures baseline metrics for rated throughput, latency, and expected errors based on the physical cable infrastructure, including patch panels.

3.3 Predeployment Cabling and Optics Validation

Brocade Gen 5 or later switches equipped with 16G FC or faster optics are capable of ClearLink® Diagnostics. ClearLink enables pre-deployment testing to validate the integrity of the physical network infrastructure before operational deployment. Part of Brocade Fabric Vision®, a ClearLink Diagnostic Port (D_Port) converts a Fibre Channel production port into a diagnostic port for testing components and traffic. The test results can be beneficial in diagnosing a variety of port and link problems. ClearLink Diagnostics is an offline diagnostics tool that allows users to perform an automated battery of tests to measure and validate maximum throughput speeds, latency, and distance across fiber infrastructure. ClearLink Diagnostics can verify the health and integrity of transceivers. Before deployment, users should conduct diagnostics to vet potential CRC errors caused by physical-layer issues, such as dirty optics, bad cables, and broken connectors.

A D_Port requires the production port to be offline. All other production ports are unaffected. A D_Port can test links to a new fabric switch without allowing the new switch to join the fabric.

ClearLink Diagnostics is a fabric-based, physical-layer validation that enables the following metrics:

- Transceiver health check
- Transceiver uptime
- Long-distance measurements – Link distance is reported for links 1 KM or longer
- Link latency measurements between D_Ports
- Link power loss (dB)
- Link performance

Refer to the *Brocade Fabric OS Troubleshooting and Diagnostics User Guide* for a more detailed discussion of D_Port usage.

Refer to “Appendix A: ClearLink Diagnostics” in the *SAN Fabric Resiliency and Administration Best Practices User Guide* for details on enhancements in each FOS release.

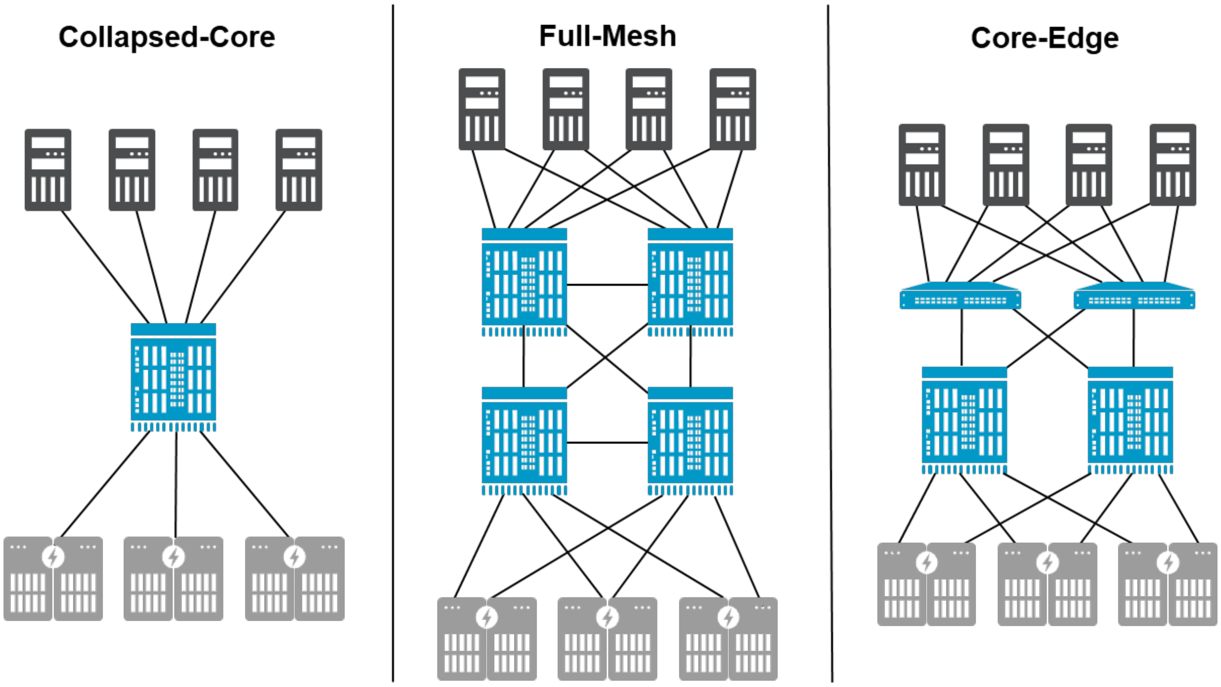
Chapter 4: SAN Design Basics

This chapter provides high-level guidelines for architecting a typical SAN. The focus is on best practices for collapsed-core, core-edge, and mesh fabrics. The discussion starts at the highest level, the data center, and works down to the port level, providing recommendations at each point along the way.

4.1 Topologies

A typical SAN architecture comprises edge devices, network devices, and cabling. Topology is usually described in terms of interconnected switches, such as collapsed-core, core-edge, and full-mesh. The recommended SAN topology to optimize performance, availability, management, and scalability is a tiered, core-edge topology. The core-edge approach provides good performance without unnecessary interconnections. At a high level, the tiered topology has a large number of edge switches used for device connectivity and a smaller number of core switches used for routing traffic between the edge switches, as shown in Figure 2.

Figure 2: Three Scenarios of Tiered Network Topologies



The difference between these three scenarios is device placement, where devices are attached to the network and the associated traffic flows.

- Scenario A: A collapsed-core localizes traffic to a single platform. Each ASIC performs cut-through switching. The receiving ASIC either switches a flow out to the end device or sends it to the next closer ASIC. A collapsed-core can have small performance advantages for performance-critical, latency-sensitive workloads. Local switching does not scale beyond an ASIC's port group. A collapse-core architecture significantly reduces manageability by having one platform per fabric. The overall number of fabrics determines manageability.
- Scenario B: A core-edge separates storage and server connectivity, thus providing ease of management and greater scalability. A core-edge topology has only one fabric hop from server to storage, providing identical performance as full-mesh while allowing greater scalability.
- Scenario C: A full-mesh fabric has no more than one hop between server and storage, assuming the server and storage are not connected to the same platform. Designing fabrics with UltraScale ICLs is an efficient way to save valuable FC ports. Using best-practice SAN design considerations, users can quickly build a large fabric with 3456 ports or more.

4.1.1 Collapsed-Core

The collapsed-core topology (Figure 2) places initiators (servers) and storage (targets) on the same chassis and potentially the same blade and ASIC. This topology has several benefits depending on the size of the environment. Collapsed-core is used when customers migrate from multiple switches to a single, dual-core architecture in which all initiators and targets fit. Moving to a core-edge architecture is best if future design requirements include increasing capacity.

4.1.2 Core-Edge

The core-edge topology (Figure 2) places initiators (servers) on the edge tier and targets (storage) on the core tier. For redundancy, each fabric (A and B) has two cores. Since servers and storage are on different switches, this topology provides easy management, outstanding performance, and minimal latency, with data flows traversing one hop from edge to core. Storage-to-storage traffic will require two hops if the second storage platform destination is not connected to the same core. The two cores within the same fabric can be connected if storage-to-storage connectivity is required. The disadvantage to a core-edge design is that storage and core-to-edge connections contend for expansion as the environment scales; however, director platforms are flexible, allowing ICLs for inter-switch connectivity and freeing up ports for additional devices.

4.1.3 Full-Mesh

A full-mesh topology (Figure 2) allows you to place servers and storage anywhere since communication between source and destination is no more than one hop. This design uses director-class switches with UltraScale ICL ports for interconnectivity to ensure maximum device port availability and utilization. Design this architecture with a minimum of two switches and up to nine in a full mesh.

4.2 High-Performance Latency-Sensitive Workloads

Over the last few years, enterprises have come to leverage low-latency, high-throughput flash arrays for demanding, performance-sensitive workloads. Brocade Gen 7 Fibre Channel is ideally suited for these workloads due to the sub-microsecond latency through the switch and the high-speed bandwidth while providing accurate I/O instrumentation. Performance testing has shown that all-flash arrays realize dramatic benefits connected to Gen 7 HBAs and SAN, with gains of up to 2x over Gen 5 and Gen 6.

The Gen 6 and Gen 7 standards include forward error correction (FEC) to ensure transmission reliability and a highly deterministic data flow. FEC corrects up to 140 corrupt bits per 5280-bit frame at the receiving end of the link, avoiding the need to retransmit frames when bit errors are detected.

For highly demanding workloads, a no-hop fabric connection through a one-ASIC switch like the Brocade G720 or local switching within an ASIC on a director's port blade minimizes latency to sub-microsecond speeds. Local switching performs cut-through switching of FC frames from the ingress port to the egress port when in the same port group. Some platforms, like the X6/X7 directors and G730 switches, contain multiple switching ASICs between data ingress and egress; however, keeping host and storage connections within an ASIC's port group minimizes latency slightly and avoids moving data between ASICs.

For details on port groups and local switching, refer to the *Brocade Fabric OS Administration Guide* and the hardware installation guide for the appropriate product.

4.3 Redundancy and Resiliency

An essential aspect of SAN architecture is fabric resiliency and redundancy. The objective is to remove a single point of failure. Resiliency is the network's ability to continue functioning after a failure. Redundancy describes the duplication of components, typically the entire fabric, to eliminate a fabric failure as a single point of failure.

Brocade fabrics have resiliency built into FOS, which runs on all Brocade platforms. FOS can repair and overcome failures. For example, fabric shortest path first (FSPF) computes a new path when a fabric topology changes, like when a link goes offline, assuming a second path exists when fabric resiliency is essential.

The key to high availability and enterprise-class availability is redundancy. Business continuance is provided through most foreseeable and unforeseeable events by eliminating an entire fabric as a single point of failure. At the highest level of fabric design, the complete fabric should be redundant, with two mirrored, entirely different fabrics that do not share any common SAN platforms.

Servers and storage devices should be connected to both fabrics (A and B), leveraging some form of multipath I/O (MPIO) so that data can flow across both fabrics seamlessly in an active/active or active/passive mode. MPIO ensures that an alternate path is available if the current path fails. Ideally, redundant fabrics are identical, but they should be based on the same switches to ensure consistency of performance and delivery. In some cases, these fabrics are in the exact location. However, two separate locations are often used to provide for disaster recovery (DR), either for each complete fabric or sections of each fabric.

Regardless of the physical geography, there are two different fabrics for complete redundancy.

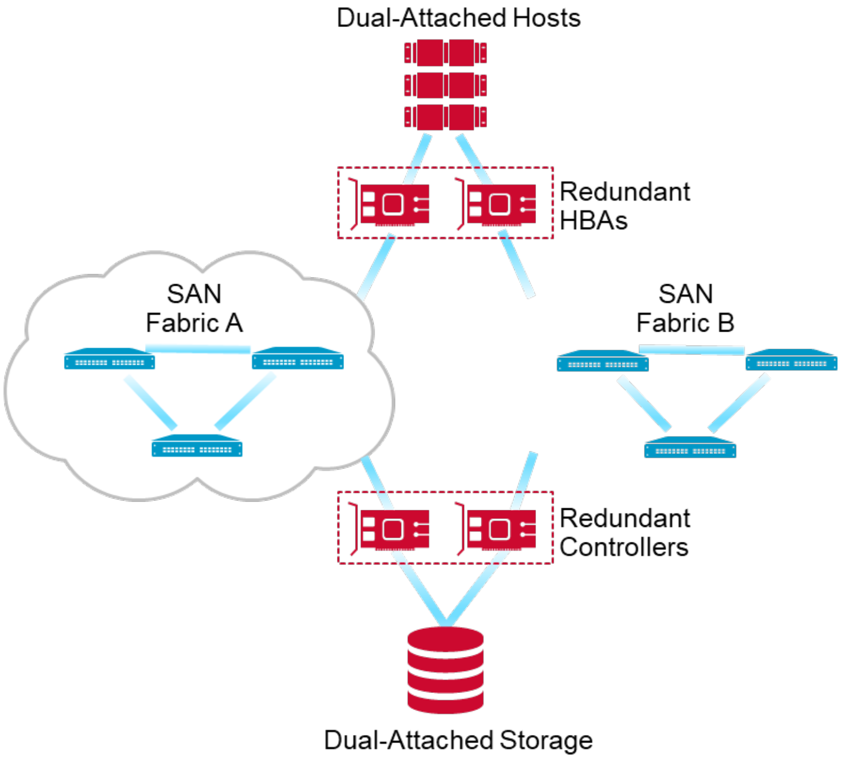
In summary, best practices for SAN design are to ensure application availability and resiliency through the following methods:

- Fabric redundancy to avoid a fabric being the single point of failure
- Resiliency is built into each fabric to avoid a single point of failure
- Redundant connections from each host to each fabric
- MPIO-based failover from initiator to target
- Identical architectures and platforms in each fabric
- Redundant ISL, inter-fabric link (IFL), and ICL for inter-switch connectivity
- Separate storage (core tier) and server (edge tier) tiers for independent expansion
- Core switches of equal or higher performance compared to the edge switches
- Defining the principal switch to be the highest-performance switch in the fabric

4.4 Switch Interconnections

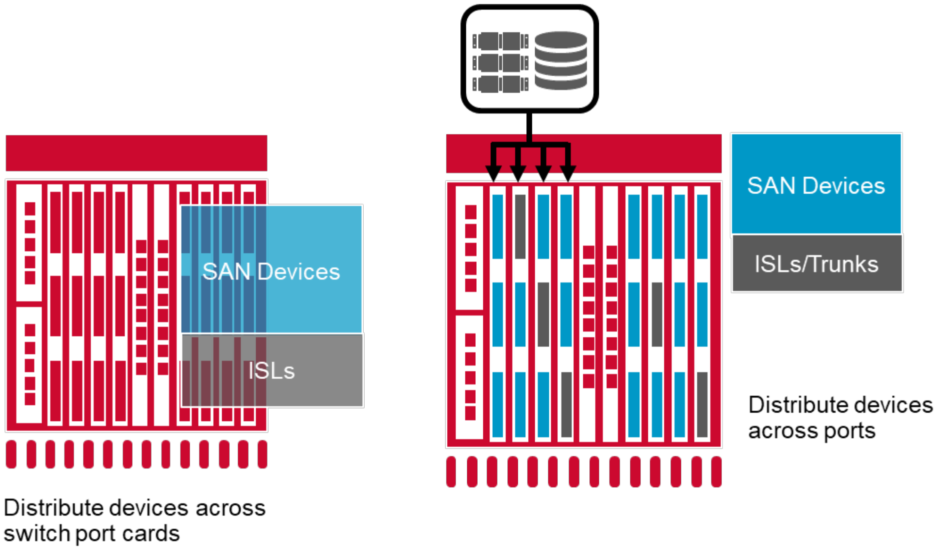
As mentioned previously, at least two of every element in the SAN should provide redundancy and improve resiliency. The number of available ports and device locality (server/storage tiered design) determines the number of ISLs needed to meet performance requirements. ISL requirements for directors include a minimum of two trunks with at least two ISLs per trunk. Each source switch should be connected to at least two other switches, and so on. In Figure 3, each blue connection line represents at least two physical cables. Two physical connections provide redundancy for ports, optics, fiber patch cables, patch panels, and fiber infrastructure.

Figure 3: Connecting Devices through Redundant Fabrics



Redundant trunks on a director platform should be placed in varying port groups on different blades, as shown in Figure 4. See the appropriate hardware manual to determine port groups for the various models of port blades. For more details, refer to the *Brocade Fabric OS Administration Guide*. Whichever method is decided upon, it is crucial to be consistent across the SAN. For example, do not place ISLs on lower port numbers in one chassis, as shown on the left in Figure 4, and stagger ISLs on a different chassis, as shown on the right in Figure 4.

Figure 4: Examples of Distributed ISL Placement for Redundancy

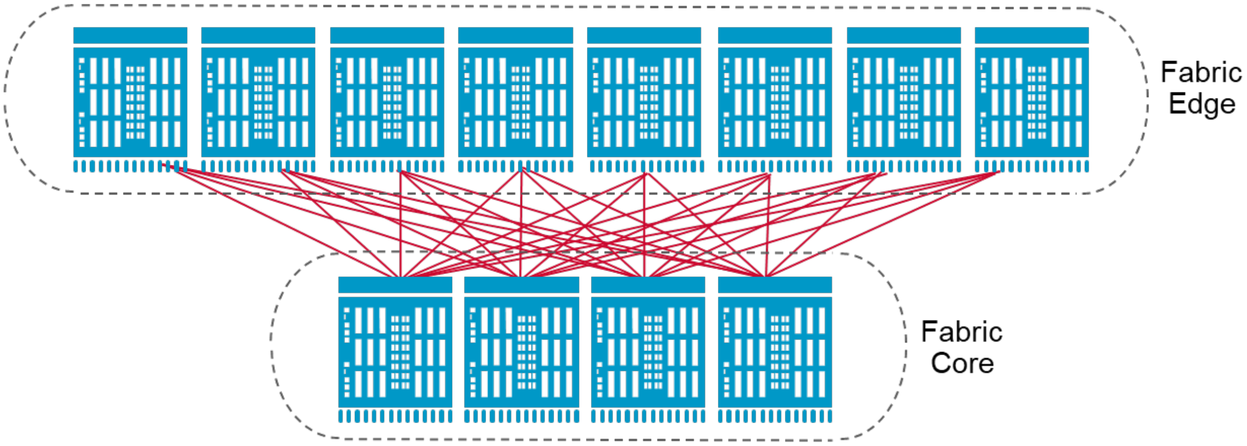

SAN Devices
ISLs
Distribute devices across switch port cards
SAN Devices
ISLs/Trunks
Distribute devices across ports

NOTE: In Figure 4, ISL trunks are placed on separate ASICs or port groups. It is essential to match ISL placement between devices and across fabrics to ensure simplicity in design and assist in problem investigation.

4.4.1 UltraScale ICL Connectivity

The Brocade X6 and X7 platforms use second-generation UltraScale ICL technology from Broadcom with optical QSFPs. The Brocade X6-8 and X7-8 support up to 32 QSFP ports per chassis (Figure 5), and the Brocade X6-4 and X7-4 support up to 16 QSFP ports per chassis. UltraScale ICL technology preserves FC ports for connections to end devices. Each ICL port has four independent links that terminate on a different ASIC.

Figure 5: Twelve-Chassis UltraScale ICL-Based Core-Edge Design

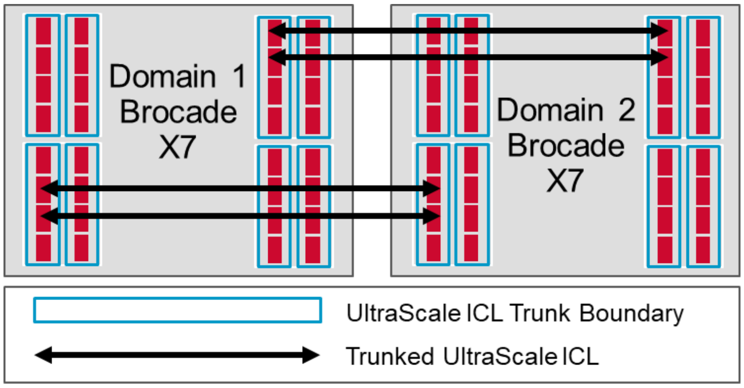


4.5 Brocade UltraScale ICL Best Practices

Each core blade in a chassis must be connected to each of the two core blades in the destination chassis to achieve full redundancy (Figure 6). In Figure 5, each director has 32 ICL ports, 16 on each core routing blade. There are eight edge directors and four core directors. Each edge director has two connections from each core routing blade to each core director's corresponding core routing blade. Each core director connects to the edge directors using (8 edge directors × 2 connections each × 2 core routing blades each) = 32 connections.

NOTE: A pair of ICL links are used to connect core routing blades for redundancy.

Figure 6: Minimum ICL Connections Needed between Brocade X7 Chassis

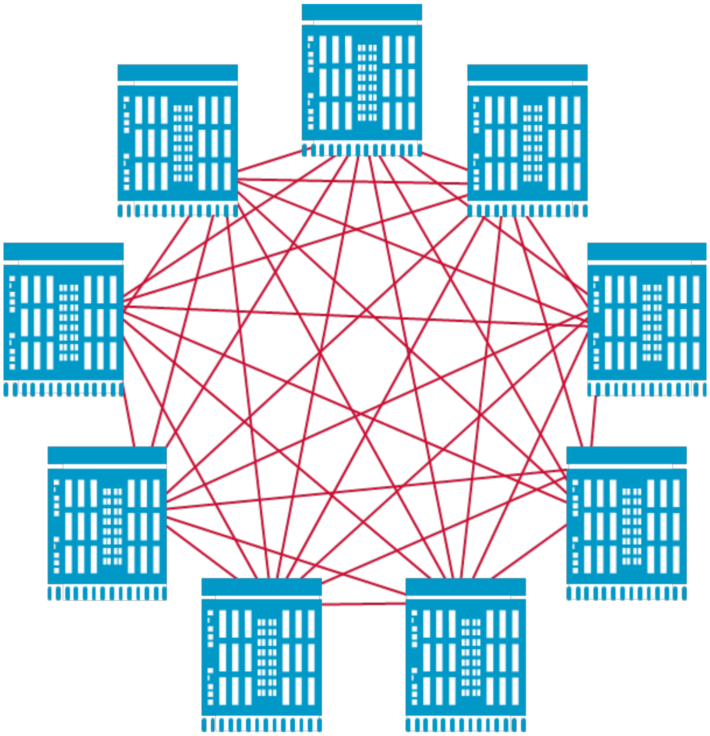


4.6 Full-Mesh Topology

A full-mesh architecture provides a single hop between source and destination. Broadcom supports a nine-director ICL mesh with up to 100-meter distances using select QSFPs and OM4 fiber. In the example shown in Figure 7 up to 4608 (nine X7 directors × eight blades in each director × 64 ports on each blade) 64G FC device ports are supported using UltraScale ICLs with a 512 Gb/s ICL (two ICL links × 256 Gb/s for each ICL link) between each director.

Alternatively, if the full-mesh had five directors instead of nine, there would be 2560 end-device 64G FC ports with 1 Tb/s between each director using ICL connectivity.

Figure 7: Nine-Chassis UltraScale ICL-Based Full-Mesh Topology



NOTE: Refer to the *Scale-Out Architecture with Brocade UltraScale Inter-Chassis Links Design Guide* for details.

UltraScale ICL connections are considered a *hop of no concern* in a FICON fabric.

In a core-edge architecture, the edge switches should connect to two core switches using Brocade Trunks (BTs) with at least two ISLs. Each BT should be attached to a different blade. Redundancy requires a second mirrored fabric, and end devices must be connected to both fabrics using MPIO to manage active/active or active/passive flows, and failover/failback flows.

The following recommendations are for ISL and UltraScale ICL connectivity:

- There should be at least two mirrored fabrics.
- There should be at least two core switches per fabric.
- Every edge switch should have at least two BTs to each core switch.
- Create small trunks. Keep BTs to two ISLs unless high traffic volumes are anticipated. Small trunks ensure that losing a BT does not result in losing significant bandwidth.
- Plan BTs based on one BT being offline.
- Place redundant BTs on different blades.
- BTs form only within a port group; port groups are in an ASIC boundary.
- Cable length difference within a BT should be identical for optimal performance.
- Use the exact cable length for UltraScale ICL connections.
- Use ISL or UltraScale ICL connectivity between the same domains; mixing the two types of connectivity is not supported.
- Use the same optic type on both ends of an ISL:
  - Short-wavelength multi-mode optical fiber (SWL MMF)
  - Long-wavelength single-mode fiber (LWL SMF)
  - Extended-long-wavelength single-mode fiber (ELWL SMF)

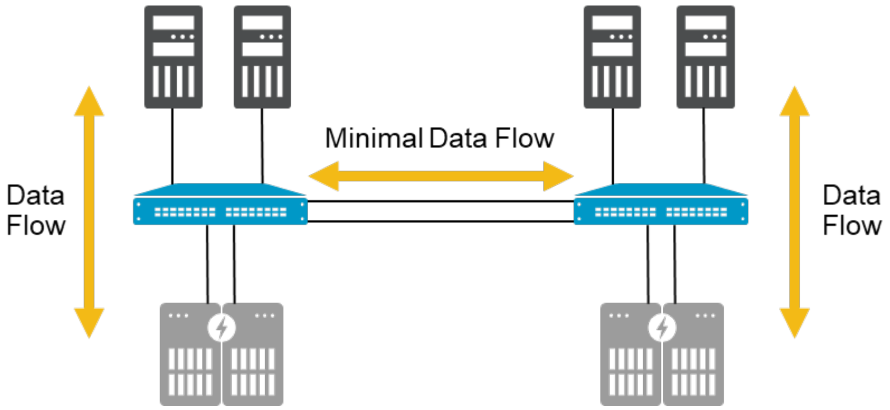
4.7 Device Placement

Device placement is a balance between traffic isolation, scalability, manageability, and serviceability. Virtualization has dramatically optimized compute platforms, driving the need for high performance and improved scalability in storage networks. Frame congestion can become a severe concern if there are end-device issues.

4.7.1 Traffic Locality

Designing device connectivity depends significantly on the expected data flow between devices. For simplicity, communicating hosts and targets can be attached to the same switch (Figure 8).

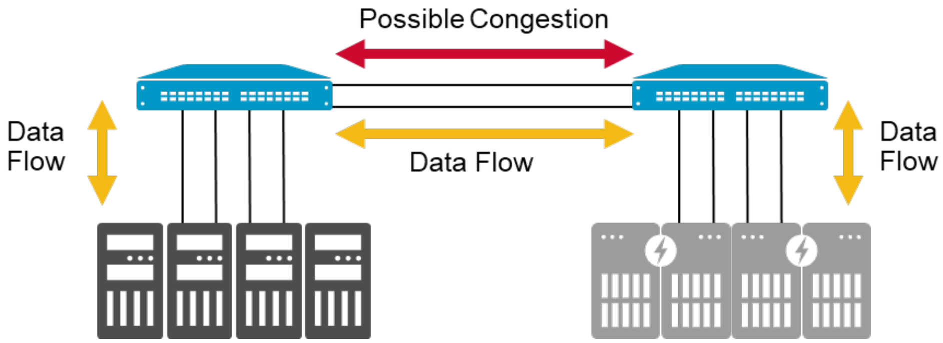
Figure 8: Hosts and Targets Attached to the Same Switch to Maximize Locality of Data Flow



This approach needs to scale. With Fibre Channel's high-speed, low-latency nature, attaching these host-target pairs on different switches does not mean performance is adversely impacted for typical workloads. With the current generation of switches, local switching is not required to gain performance or achieve low latency. Architects might want to switch traffic locally for mission-critical applications that depend on speedy response times.

In exceptional cases, multi-hop concerns might involve traffic congestion, specifically, inadequate inter-switch connectivity or concerns about proper resiliency (Figure 9). Often, these concerns can be mitigated by provisioning ISLs/UltraScale ICLs.

Figure 9: Hosts and Targets Attached to Different Switches for Ease of Management and Expansion



A less common scheme for scaling a core-edge architecture is dividing the edge switches into a storage/target tier and a host/initiator tier. This approach is called edge-core-edge and lends itself to easier management and expansion. End devices do not connect to the core. Host and storage platforms have different performance requirements, cost structures, and other factors that are accommodated by placing initiators and targets in different tiers.

Chapter 5: Data Flow Considerations

5.1 Fan-In Ratios and Oversubscription

A critical aspect of data flow is the fan-in ratio, which is the oversubscription of initiator ports to target ports or edge devices to ISLs. Alternatively, oversubscription can be viewed from the perspective of the storage array, referred to as the fan-out ratio. The ratio is the number of edge-device ports that share a single port, whether ISL, BT, UltraScale ICL, or target port. A BT is logically a single port. The ratio is always expressed from the single entity's point of view, such as 7:1 for seven hosts utilizing a single ISL or a single storage port.

What is the optimum number of hosts that should connect to a storage port? This question seems reasonably straightforward; however, the situation becomes complex once you consider clustered hosts, VMs, workload characteristics, and the number of LUNs per server. Determining how many hosts to connect to a particular storage port can be narrowed down to three considerations: port queue depth, IOPS, and throughput. Of these three, throughput is the only network component; thus, does a simple calculation adding up the expected peak bandwidth for each host suffice?

In practice, it is improbable that all hosts perform simultaneously at their maximum level. The bandwidth of the HBA was considerably overprovisioned with traditional application-per-server deployments. However, the game changed radically with virtual machines (KVM, Xen, Hyper-V, proprietary UNIX OSs, and VMware). Conceptually, oversubscription is built into virtual machines to optimize server resources. To the extent that servers optimize their resource utilization should proportionately increase their port utilization. Fewer virtual machine ports can oversubscribe a target port compared to non-virtualized machines. Nonetheless, it is prudent to oversubscribe ports to balance cost and performance. The difficult question is, by how much?

Another method is to assign host ports to storage ports based on the I/O capacity requirements of the host. The intended result is a small number of high-capacity servers assigned to each storage port, effectively resulting in many low-capacity VM workloads distributed across the storage ports.

Port monitoring should determine the actual port utilization from fan-in and fan-out ratios, driving necessary adjustments. Ongoing monitoring provides valuable heuristic data for the successful expansion of storage and the efficient assignment of storage ports. A simple calculation method best determines the device-to-ISL fan-in ratio.

Chapter 6: Scalability and Performance

Broadcom products are designed with scalability, knowing that most installations will continue to expand and that growth is supported with few restrictions. However, following the same basic principles outlined in previous sections as the network grows will ensure that the levels of performance and availability will continue.

Evaluate the impact on topology, data flow, workload, performance, and perhaps most importantly, redundancy and resiliency of the fabric when one of the following actions is performed:

- Add, move, change, or remove applications and traffic flows (databases)
  - Changes in workflows
  - Changes in provisioning
- Add, move, change, or remove initiators (hosts):
  - Changes in hardware (memory, processors, NIC, HBA, and so on.)
  - Changes in virtualization
  - Changes in provisioning
- Add, move, change, or remove targets (storage):
  - Chnages in virtualization
  - Changes in provisioning
  - Changes in storage media type (for example, HDD versus SSD)
- Add, move, change, or remove fabric switches (Gen 5 versus Gen 7)
- Add, move, change, or remove ISLs and ICLs (16G FC versus 64G FC)

If these best practices are followed when the fabric is deployed, small incremental changes should not adversely impact the availability and performance of the fabric. However, ongoing changes can negatively affect performance and availability if the fabric is not updated or adequately evaluated.

Some key points to cover when looking at the current status of a production SAN include:

- **Reviewing redundancy and resiliency:**
  - Are there two or more redundant fabrics?
  - Are there two or more physically independent paths between each source (initiator) and destination (target) pair?
  - Does each host connect to two different edge switches?
  - Are edge switches connected to at least two different core switches?
  - Are inter-switch connections composed of two trunks of at least two ISLs?
  - Does each storage device connect to at least two different edge switches or separate port blades?
  - Are storage ports provisioned such that every host has at least two ports through which it can access LUNs?
  - Are redundant power supplies attached to different power sources?
  - Are zoning and security policies configured to allow patch/device failover?

- **Reviewing performance requirements:**
  - Host-to-storage fan-in and fan-out ratios
  - Oversubscription ratios:
    - Host to ISL
    - Edge switch to core switch
    - Storage to ISL
  - Size of BTs
  - Routing policy and currently assigned routes (evaluate actual utilization for potential imbalances)
  - Use of FEC for all ISLs and connections to Gen 6 and Gen 7 devices
- **Watching for latencies because of the following:**
  - Poor storage performance
  - Overloaded hosts or applications
  - Distance issues over constrained long-distance links resulting from changes in usage, such as adding mirroring or too many workloads
  - Deteriorating optics resulting in declining signal strength and increased error rate

In Gen 6 and Gen 7 networks, storage response latency can be baselined and monitored continuously using IO Insight in conjunction with Monitoring and Alerting Policy Suite (MAPS). Deal with latencies immediately; they can impact the fabric profoundly.

In summary, although a Brocade SAN allows for any-to-any connectivity and supports provision-anywhere implementations, these practices can harm performance and availability if left unchecked. As detailed above, the network needs to be monitored for changes and routinely evaluated for meeting redundancy and resiliency requirements.

Chapter 7: Supportability

Supportability is a critical part of deploying a SAN. Follow the guidelines in this chapter to ensure that the data needed to diagnose fabric behavior or problems has been collected.

- Follow Brocade's management interface best practices for connecting to the data center LAN. Set up a different VLAN (broadcast domain) for the management interfaces belonging to each fabric and route between the VLANs. Do not put the management interfaces from fabric A in the same VLAN as the management interfaces from fabric B. This separation is part of the *air gap* between the fabrics for redundancy.
- Implement a serial console server. Implement remote serial access to fabric switches for times when there are network problems or issues involving a firmware upgrade or switch boot.
- Require every user to have a AAA account for logging in so that individual user actions are tracked. Configure individual user accounts on LDAP, RADIUS, or TACACS+, and make personalized user accounts mandatory as part of a security policy.
- Restrict access by assigning or creating a pertinent role to each user.
- Enable auditing. Keep track of which administrator made what changes and when, only use individual user AAA accounts, and enable change tracking along with error logs and syslog forwarding.
- Enable Brocade MAPS. Leverage MAPS to implement proactive monitoring of errors and warnings such as CRC errors, loss of synchronization, and high-bandwidth utilization.
- Configure syslog forwarding. Troubleshooting can be expedited and simplified by sending log messages to a centralized syslog server. Forwarding messages to a syslog server is a simple monitoring functionality that historically maintains messages and expedites troubleshooting.
- Configure an NTP server. Configure switches to use an external time server to keep a consistent and correlative date and time on all messages sent to a syslog server or other management devices.
- Create a switch configuration template in SANnav to avoid configuration drift over time. You can adapt existing configurations as a template for quickly deploying new switches and ensuring consistency across the data center.
- Establish a testbed. Avoid missteps in a production environment. Set up a testbed to test: configuration changes, new applications, firmware updates, driver functionality, and scripts. Validate functionality and stability with rigorous testing in a test environment before deploying into the production environment.
- Use aliases to give switch ports and devices meaningful names for faster troubleshooting.
- Configure supportftp for automatic file transfers. The parameters set by this command are used by supportSave and traceDump.

7.1 Firmware Upgrade Considerations

Both fixed-port and modular switches support hot code load for firmware upgrades.

- Disruptive versus nondisruptive upgrades:
  - Simultaneous upgrades on neighboring switches
  - Standard FC ports versus application and special-feature ports
- Review the *Brocade Fabric OS Release Notes* for the following:
  - Upgrade path
  - Changes to feature support
  - Changes to backward compatibility
  - Known issues and defects

Consider a different Access Gateway firmware upgrade strategy. Brocade Access Gateways have no fundamental requirement to be at the same firmware release level as Brocade FOS. Upgrading only directors and switches minimizes the infrastructure changes required during an upgrade cycle.

Chapter 8: Monitoring

8.1 Brocade Fabric Vision Technology

Organizations need help managing data growth, protecting data, and leveraging actionable intelligence from data, all while meeting a strict SLA. As a result, even well-managed IT organizations must often make difficult choices about resource allocation, weighing the benefits of focusing more resources on monitoring and less on planning or optimizing. With Brocade Fabric Vision technology, organizations can achieve unprecedented insight and visibility across their critical storage network through monitoring and diagnostic capabilities.

8.1.1 MAPS

MAPS is a health and threshold-based monitoring tool that allows for autonomous self-monitoring of directors and switches in the fabric. It helps detect potential and active problems, automatically alerting users to those problems long before they become costly outages. MAPS is a part of the Brocade Fabric Vision feature set.

MAPS tracks a variety of SAN fabric health categories and events. Monitoring fabric-wide events, ports, bit errors, and environmental parameters enable early fault detection and isolation as well as a means to measure performance. All health monitoring categories are customizable, providing flexibility around how and what users want to monitor. Create your own monitoring groups, assign custom thresholds, and with FOS 9.0 and above, gain the same monitoring capabilities at a flow level. MAPS means users can now threshold-monitor application flows for abnormal completion times to manage SLAs. Users can also easily integrate MAPS with enterprise operations solutions.

MAPS also provides predefined monitoring policies for users to get a quick start. These policies provide thresholds from 20 years of best practices and customer experiences. Users can select from conservative, moderate, or aggressive policies based on how closely users want to monitor their SAN environment. If the default policies do not meet your needs, customize the thresholds and actions, and activate your custom policy. MAPS provides notifications before problems arise, such as reporting overutilized ports approaching specified bandwidth limits, potentially leading to congestion. These insights enable SAN administrators to perform preemptive network maintenance, such as trunking or zoning, avoiding potential network failures.

MAPS lets you define how often switches and fabric elements are measured while specifying notification thresholds. Whenever fabric elements exceed these thresholds, MAPS can take action. These actions include administrative notifications using email, SNMPv3, RASlog, and automated actions, such as Slow Drain Device Quarantine (SDDQ), FPIN, and in some cases, port disable.

8.1.1.1 MAPS Recommendations

Brocade MAPS is a recommended optional feature that provides threshold monitoring of multiple switch elements. MAPS monitors ports based on type, each with unique monitoring and alerting thresholds. Different port types (F_Ports, E_Ports, VE_Port, and N_Ports) have different characteristics. MAPS provides flexibility in monitoring and alerting to address various cases.

MAPS allows for the monitoring and alerting of IO Insight flow metrics, which provides SAN admins with notifications of performance degradation. An early alert of flow degradation could indicate congestion and associated response time impact. When support for VM Insight is enabled, it can identify potential end-to-end issues from an individual VM to its LUN.

8.1.1.2 Tips on Getting Started with MAPS

Are you new to the Brocade Monitoring and Alerting Policy Suite and want to start monitoring your SAN? MAPS provides deep insights into SAN health and performance with a single click. The following sections provide tips on the initial use of MAPS. A Fabric Vision license enables over 300 additional rules and is required to take advantage of all monitoring capabilities.

When starting with MAPS, SAN admins should monitor their fabric with one of the three predefined policies (conservative, moderate, and aggressive). Start with the conservative policy to understand better what MAPS monitors, the severity of set thresholds, and the generated alerts. If the conservative policy is not meeting your needs, switch to either the moderate or aggressive policy. SAN admins can personalize default policies with their observed thresholds and desired actions to fit their environment better. SAN administrators can implement policy customization and management through the Brocade SANnav™ Management Portal or the CLI.

The following items are some examples of customization:

- Clone predefined policies for customizations of individual thresholds and rules.
- Create custom monitoring groups, for example, ports, SFPs, and application flows.
- Distribute policies across the SAN for uniform fabric monitoring.
- Configure MAPS actions and take advantage of automated problem mitigation.
- Create custom MAPS monitoring dashboards through SANnav Management Portal.

8.1.2 Fabric Performance Impact Monitoring

Fabric Performance Impact (FPI) monitoring leverages predefined MAPS policies to automatically detect and alert administrators to the severity of latency and identify slow drain devices that could impact network performance. FPI detects various latency severity levels, pinpointing which devices are causing backpressure in the fabric and impacted by a bottlenecked port. MAPS and FPI work together to quarantine slow drain devices to prevent buffer credit starvation automatically.

8.1.3 SDDQ Explained

Lost buffer-buffer-credits (BBCs), credit-stall, and oversubscription lead to fabric congestion and backpressure. Backpressure potentially affects neighboring flows, referred to as victim flows, resulting in widespread performance degradation. The fabric uses automated SDDQ to mitigate backpressure using MAPS.

SDDQ works with MAPS and FPI monitoring to detect congestion scenarios and isolates problematic devices to a low-priority virtual channel (VC). By default, in a Brocade fabric, traffic runs on medium-priority VCs. Frame loss, oversubscription, and impacted fabric performance cause SDDQ to automatically and non-disruptively quarantine egregious flows. The action MAPS takes is enabled individually for these conditions. Once problematic flows are isolated, fabric backpressure is relieved, which frees BBCs in the medium-priority VCs.

Also, FPI monitoring continually checks for cleared congestion conditions on impacted devices, allowing MAPS to automatically unquarantine previously quarantined flows. The MAPS unquarantine action moves flows back into the medium-priority VCs. This process is similar to the quarantine action and is non-disruptive. The MAPS SDDQ quarantine and unquarantine actions are supported on local and remote switches attached by ISLs, and Brocade Access Gateways.

8.1.4 Flow Vision

Flow Vision is a diagnostics tool for Brocade SAN platforms. It provides traffic flow visibility in the fabric and can copy flows for later analysis. It allows test flow generation at line-rate speeds to prevalidate SAN hardware performance and connectivity. Use flow generation capability to confirm optimal health and your ability to support spikes in throughput.

For mission-critical applications, consider running Flow Vision constantly to keep a historical record of application performance profiles and intermittent irregularities. For application owners who might frequently call, run Flow Vision regularly when time permits to verify good fabric health and to preempt lurking issues.

8.1.5 IO Insight

IO Insight, also known as Flow Monitor, is supported by the Broadcom Gen 6 and Gen 7 Fibre Channel switching platforms, which provide deeper flow-level IO statistics. These statistics include storage device latency and IOPS metrics such as first IO response time, IO completion time, and the number of pending IOs for a specific initiator and target or target and LUN. IO Insight provides IO workload monitoring and early detection of storage performance degradation.

It is a best practice to monitor critical applications with IO Insight. IO Insight metrics should be added to MAPS policies to better understand IO profiles as well as to be notified of storage IO performance degradation. This reporting has tremendous value for performance-sensitive workloads, enabling administrators to meet critical SLAs. IO Insight provides feedback on device reliability and performance optimization over time. The pending IO metric measures the HBA queue depth and can fine-tune server queue depths.

Beginning with Fabric OS 9.0, IO Insight autonomously learns all flows traversing a switch with no user configuration required, as it is enabled by default. Once switches are discovered through SANnav Management Portal, telemetry data is automatically propagated to the management platform, which is utilized for flow-level and application-level investigation.

Refer to the *Brocade Fabric OS Flow Vision User Guide* for configuration and usage details on Flow Vision and IO Insight.

8.1.6 VM Insight

The VM Insight feature provides the same IO and performance-level metrics that IO Insight provides for individual virtual machines. This feature distinguishes individual VM flows down to the LUN, even if other VMs share the same LUN. VM Insight has unprecedented visibility and monitoring of VM application health and performance. It integrates with MAPS, allowing users to threshold-monitor and alert VM flow-performance deviations similar to IO Insight.

This feature is available on Gen 6 platforms running Fabric OS 8.1 and later, and on all Gen 7 platforms.

8.2 SANnav Management Portal Monitoring Overview

SANnav Management Portal is Broadcom's GUI-based management platform, tightly integrating with Fabric OS. From feature configuration to analysis of gathered telemetry data and events, SANnav provides actionable insight to SAN administrators.

Brocade SANnav uses Fabric OS features to detail device health, congestion, and flow telemetry, investigate concerns, troubleshoot issues, and customize dashboards. Refer to the SANnav Management Portal and Global View documents available here for more detail around the management platform monitoring capabilities.

8.3 Troubleshooting

8.3.1 D_Port

A Brocade ClearLink D_Port enables pre-deployment testing for cable-plant infrastructure. Part of Brocade Fabric Vision technology, ClearLink is an offline diagnostics tool that allows users to perform an automated suite of tests to measure maximum throughput speeds, latency, and distance across links. ClearLink Diagnostics verifies the health and integrity of FC transceivers in the fabric. Diagnostics are conducted before production or when excessive CRC errors occur.

A D_Port requires that the production port be taken offline. All other ports remain online and are isolated from D_Ports. ClearLink can also be used to test links to a new fabric switch without allowing the new switch to join or even be aware of the current fabric, providing an opportunity to measure and test ISLs before they are put into production.

ClearLink Diagnostics is a fabric-based, physical-layer validation that enables the following metrics:

- Transceiver health check
- Transceiver uptime
- Link power (dB) loss
- Link performance

8.3.2 Recommendation: D_Port On-Demand

When an on-demand D_Port-capable switch or chassis comes online, the switch checks if the other end of the connection supports dynamic D_Port mode. If dynamic D_Port is supported on the opposite end, the switch changes the remote port to D_Port mode and starts a diagnostic test automatically. After completing the test, the D_Port changes to normal port mode.

For Brocade ClearLink Diagnostics guidelines and restrictions, refer to the Brocade Fabric OS Troubleshooting and Diagnostics User Guide for a more detailed discussion of diagnostic port usage.

8.3.3 FEC

FEC is a data transmission error-correcting method that includes redundant error-sensing data. Error-correcting code ensures virtually error-free transmission. FEC supports the following data transmissions:

- When 10/16G FEC is enabled, it can correct one burst of up to 11-bit errors in every 2112-bit transmission, whether the error is in a frame or a primitive.
- When 32G FEC is enabled, it can correct up to seven symbols in every 5280-bit transmission. A symbol consists of 10 bits, so there are 528 symbols in every 5280-bit transmission.
- When 64G FEC is enabled, it can correct up to 15 symbols in every 5440-bit transmission. A symbol consists of 10 bits, so there are 544 symbols in every 5440-bit transmission.

Because FEC is optional at 10G and 16G speeds, the Transmitter Training Signal (TTS) was extended to negotiate FEC capabilities. FEC is negotiated and activated when both sides of the link have FEC enabled. The FEC active indicator in Fabric OS indicates whether FEC was successfully negotiated. FEC uses unused bits within the signaling protocol to generate an error-correcting code (ECC) and correct bits as needed.

Refer to the *Brocade Fabric OS Administration Guide* for FEC configuration options and limitations.

8.3.4 Buffer Credit Loss Detection and Recovery

BBC recovery allows links to recover after losing one or more buffer credits. If a credit loss is detected, recovery initiates. BBC recovery is supported on E_Ports, EX_Ports, and F_Ports. BBC Loss Detection and Recovery enables Brocade hardware to detect and recover any lost credits on backend ports without user intervention. BBC recovery is accomplished through a link reset in which performance is maintained; frame and BBC counters are reset.

Enable credit loss detection and recovery on your Brocade platforms. This feature is disabled by default. BBC recovery is enabled automatically across long-distance connections where the E_Port, EX_Port, or F_Port recovery mechanism is supported.

8.3.5 RASLog Messages

RASLog messages report significant system events and information (failure, error, and critical conditions) and show the status of high-level user-initiated actions. RASLog messages are forwarded to the console, configured syslog servers, and configured Simple Network Management Protocol (SNMPv3) traps or informs. SANnav Management Portal can be used as a RASLog receiver.

The following are the severity levels for messages and their descriptions:

- 1 = CRITICAL

  Critical-level messages indicate that the software has detected severe problems that will cause a partial or complete failure of a subsystem if not corrected immediately; for example, a power supply failure or a temperature rise must receive immediate attention.
- 2 = ERROR

  Error-level messages represent an error condition that does not impact overall system functionality significantly. For example, error-level messages might indicate timeouts on specific operations, failures of certain operations after retries, invalid parameters, or failure to perform a requested operation.
- 3 = WARNING

  Warning-level messages highlight a current operating condition that should be checked, or it might lead to a failure in the future. For example, a power supply failure in a redundant system relays a warning that the system is no longer operating in redundant mode unless the failed power supply is replaced or fixed.
- 4 = INFO

  Info-level messages report the current nonerror status of the system components, for example, detecting the online and offline status of a fabric port.

8.3.6 Audit Log Messages

Event auditing is designed to support post-event audits and problem determination based on high-frequency events, such as security violations, zoning configuration changes, firmware downloads, and certain fabric events. Audit messages flagged as only AUDIT are not saved in switch error logs. Audit messages can be streamed to the console and forwarded to syslog servers. Audit log messages are not forwarded to SNMP. There is no limit to the number of audit events.

For any given event, audit messages capture the following information:

- Date and time.
- Platform name.
- User Name: The name of the user who triggered the action.
- User Role: The access level of the user, such as root or admin.
- Event Name: The name of the event that occurred.
- Event Information: Information about the event.

8.4 Monitoring the Switches

Consider implementing some form of monitoring of each switch. Issues often start relatively benign and gradually degrade into more severe problems. Monitoring the logs for warning, critical, and error severity messages will go a long way in avoiding many problems. Consider the following actions:

- Plan a centralized collection of RASLogs and perhaps Audit logs through syslog. You can optionally filter these messages relatively easily through some simple scripting programs, or you can perform advanced correlation using an event management engine.
- Brocade platforms are capable of generating SNMP traps for most error conditions. Consider implementing some sort of alerting mechanism through SNMP or email notifications.

8.5 Latencies

Latency has many causes:

- Slow devices such as hosts and storage arrays
- Oversubscribed devices
- Long-distance links
- Servers that are not responding rapidly to previous I/O requests
- Degraded cables and failing SFPs due to I/O retries

Very little can be done in the fabric to accommodate end-device latencies, typically addressed through other means. Applications might require tuning to improve performance. Array latencies are dealt with through array and LUN reconfiguration, data migration, and technology refresh. Long-distance problems might require more bandwidth or adjustment of the switches' distance settings. Failing fiber infrastructure and SFPs must be identified and replaced. At best, Brocade fabrics can help identify problem sources. Broadcom has worked diligently to enhance Fabric OS RAS features congruent with ever-changing customer requirements. Some of these features are described briefly in the following sections.

8.6 Misbehaving Devices

All fabrics are vulnerable to the effects of misbehaving devices, that is, a server or storage device that stops functioning correctly. The effects of misbehaving devices can be severe, causing other applications to fail intermittently, failover, or stop altogether. Broadcom has implemented several new features designed to detect misbehaving devices and isolate them from other devices in the fabric.

Isolating a single server has much less impact on applications than disabling a storage array port. Typically, a storage port services many applications, and the loss of that storage can severely impact all connected applications. One of the advantages of a core-edge design is that it is straightforward to isolate servers from their storage and ensure that any action applied to a host port for a given behavior can be very different than the action applied to a storage port for the same behavior.

Detailed guidance on monitoring for misbehaving devices and configuring fabrics to respond to developing issues can be found in the *SAN Fabric Resiliency and Administration Best Practices User Guide*.

8.7 Design Guidelines

Consider the following design guidelines:

- **Transaction-based systems**: Ensure that the ISLs or UltraScale ICLs that are traversed by transaction-based systems accessing storage do not contain excessive flows. The fan-in from initiators should not exceed a ratio of 10 to 1. Also, ensure that there is as little interference from other applications as possible so that latencies and congestion from other sources (called perpetrator flows) do not affect the overall performance of the applications (called victim flows).
- **I/O-intensive applications**: Bandwidth is the most common constraint for I/O-intensive applications. Modern fabrics provide more bandwidth than needed except for the most powerful hosts. Ensure that high-performing systems do not interfere with other applications, particularly if utilization spikes are scheduled at specific times or batches. Add more paths, ISLs, or trunks when in doubt.
- **Clusters**: Clusters often have behavioral side effects, particularly during storage provisioning. A cluster inundating a fabric and storage array with LUN status queries and other requests can cause fabric congestion and stress array controllers. Spread LUNs across arrays.
- **Congestion**: In some cases, traffic congestion can be remedied by adding more ISLs or BTs, assuming the congestion is between switches. In many cases, congestion occurs at a node or storage port. Brocade Gen 7 FPIN technology mitigates end-device congestion issues. Configure end devices with modern HBAs and drivers to optimize traffic across lossless FC fabrics that use FPIN.
- **Misbehaving devices**: Little can be done in the fabric to mitigate the effects of a badly behaving device other than to remove it from the fabric. Brocade Fabric OS, Port Fencing technology, is designed to isolate rogue devices. Port Fencing works with MAPS to disable a port when a specific threshold is reached. With FPI monitoring, Port Fencing can detect and isolate high-latency devices. High-latency devices frequently impact many other devices in the fabric.
- **Initiator and targets**: Isolate host (initiator) and storage (target) ports onto separate switches for more effective management and control over misbehaving and high-latency devices. The effect on an environment is often less severe if a node port is disabled than a storage port, which services many servers.

Chapter 9: FC Routing

9.1 Overview and Purpose

A large SAN might have thousands of end devices, which could inundate or exceed fabric scalability, fabric services, convergence timeliness, and user manageability. FCR constrains fabric services to an edge or backbone fabric. With FCR, fabric services do not merge beyond an edge or backbone fabric. Fabric services are self-contained within each edge fabric or backbone. An example of a fabric service is the name server.

Limiting fabric services to within each edge fabric is done for various reasons:

- The overall SAN can scale to a much larger relative size than the maximum scalability of the fabric services within each edge fabric.
- Within an edge fabric, FCR reduces switch domains and managed zones.
- Edge-fabric disturbances and reconfigurations only affect local fabric services, thereby providing fault isolation.
- FCR increases security because end devices cannot communicate outside an edge fabric unless explicitly zoned.

9.2 Edge Fabrics

Edge fabrics are traditional fabrics, except they are connected to backbone EX_Ports. Edge fabrics contain end devices and might be connected to other edge fabrics through the backbone fabric. Backbones EX_Ports connect to edge fabric E_Ports. There are no EX_Ports in an edge fabric.

Generally, edge fabrics follow the core-edge architecture, the same as traditional fabrics. Unique to FCR is edge fabric interconnectivity through a backbone.

9.3 Inter-Fabric Links

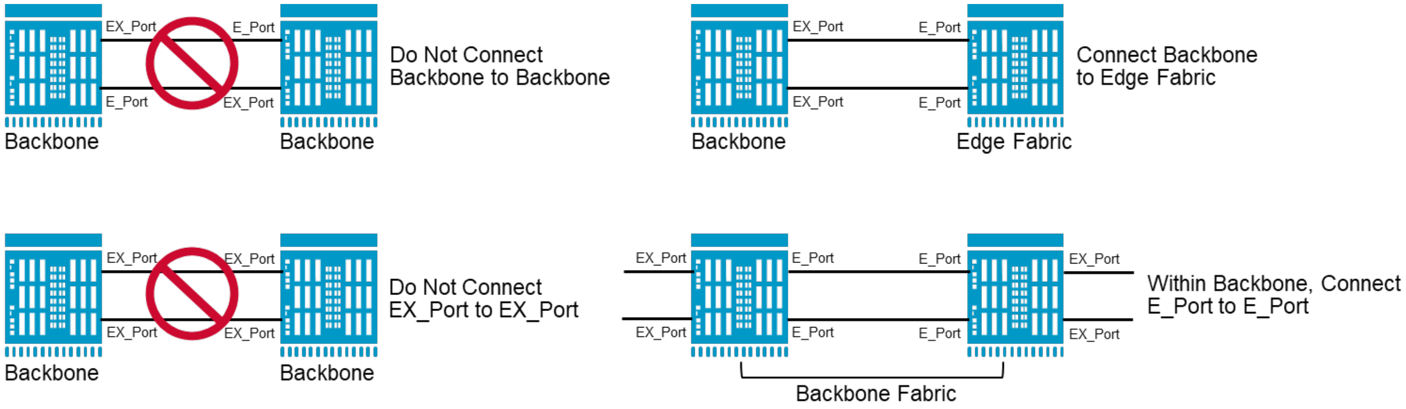
An IFL connects an EX_Port to an E_Port. It is an ISL that spans from an edge fabric to a backbone.

Provision enough IFLs between each edge fabric and the backbone to accommodate the projected peak traffic load, plus planning for IFL outages due to a bad port, optic, or cable.

9.4 Backbone Fabrics

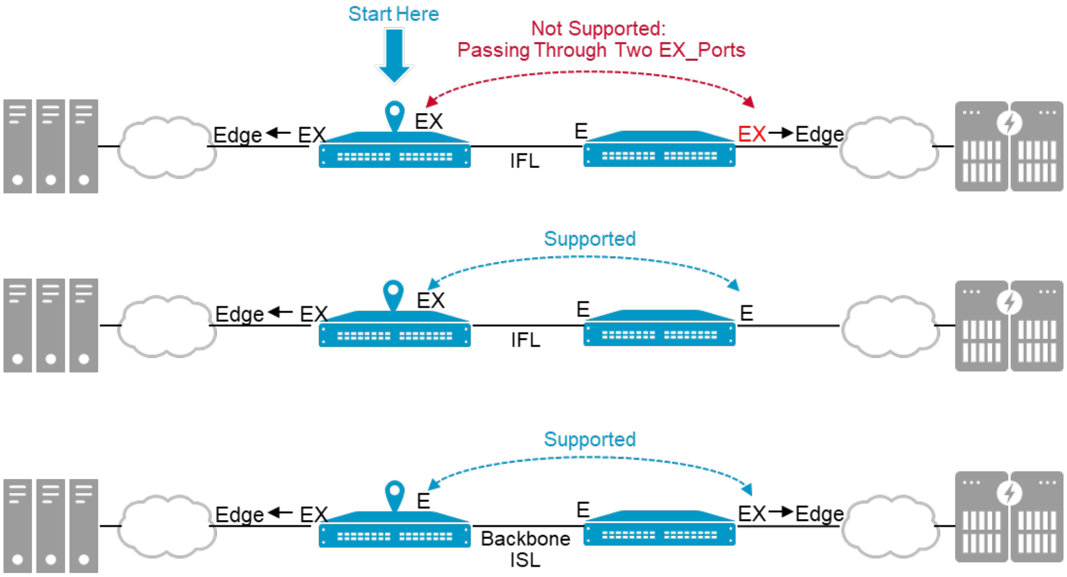
Backbone fabrics contain EX_Ports and are the boundary for fabric services. Each backbone has a unique backbone ID (BBID). A fabric can contain one or more backbones with end devices or no end devices connected. Both architectures are supported. The backbone contains the EX_Ports; EX_Ports do not exist in edge fabrics. Do not connect backbones together that have different BBIDs; see Figure 10. A backbone fabric can contain extension links, which are considered an ISLs; see Chapter 9.8, FCR and Extension.

Figure 10: Supported Backbone Architectures



EX_Ports are fabric services boundary points, and fabric services do not pass beyond an EX_Port. Two EX_Ports cannot be connected. EX_Ports only connect to E_Ports and the EX_Ports must exist on the backbone side, not the edge fabric side. Topology supportability is determined by starting within an FC router and moving to the end device. Traffic cannot pass through more than one EX_Port along the path. The architecture is unsupported if more than one EX_Port is passed, see Figure 11.

Figure 11: Supported FCR Architectures



There are many factors to consider when designing backbone fabrics. Backbone fabrics vary based on size, requirements for redundancy, and distance between edge fabrics. Generally, SAN architecture recommendations apply equally to backbone fabrics. There should be redundant fabrics, and each fabric should have redundant paths to every edge fabric. Consider the following factors when identifying the best switch platforms and backbone topology, including interconnections. The number of edge fabrics can impact the backbone topology and how they attach. Brocade FCR can be enabled on standard FC ports, but a license might be required.

Composition of edge fabrics:

- **Scale and interoperability**: Ensure that director and switch platforms can support the scale and interoperability needed.
- **Legacy SAN platforms**: Anywhere in the SAN, earlier directors/switches or firmware might impact supported features, manageability, and interoperability.
- **Advanced SAN applications and features**: Some advanced SAN applications and features might not be compatible with FCR or a particular platform type.

Projected inter-fabric traffic patterns:

- **Quantity (bandwidth utilization)**: Provision enough ISLs within the backbone to accommodate projected peak traffic loads that traverse the backbone.
- **Bursty versus peak traffic**: Bursty traffic is a sudden spike that rapidly dissipates. It is not the same as peak traffic, which might not be bursty. Infrequent, bursty traffic can be forgiving. Traffic bursts might cause temporary response time increases due to congestion. Buffer credits might be withheld until a burst subsides. Such congestion is less likely with traffic patterns of a continuous nature.
- **Small versus large frame size**: Fibre Channel is a high-speed, low-latency protocol. It relies on BBC flow control. This mechanism is a fundamental part of FC and provides lossless data communications. A sequence of small frames uses the same number of BBCs as a series of large frames. On the other hand, large frames use more bandwidth. In other words, a large amount of small-frame traffic can fully utilize available buffers while consuming only a minimal amount of bandwidth. Therefore, consider not only bandwidth but also the typical frame size. For instance, FC compression creates primarily smaller FC frames. If the bulk of frames is expected to be smaller, additional buffers should be allocated to the paths handling those I/O patterns. Pay extra attention to this type of congestion because congested backbones adversely impact the performance of all connected edge fabrics. When in doubt, overprovision IFLs.
- **Distance (location of fabrics)**: Long-distance IFLs require adequate bandwidth and BBCs to prevent data transmission congestion and droop, respectively. Consider all potential traffic flows that might traverse the long-distance links. Long-distance links have more latency, simple physics time = distance/rate. Therefore, overprovisioned long-distance links might prevent oversubscription such that unexpected bursts do not adversely impact flows.
- **Virtual Fabrics**: All EX_Ports must reside in the base switch. The base switch does not support ISL R_RDY mode. If a logical switch has XISL enabled, you cannot connect an EX_Port to that logical switch. The base switch is similar to a backbone switch, and a base fabric is like a backbone fabric. All switches in a backbone fabric must have the same backbone fabric ID, which must be unique relative to any edge fabric.

Potential growth:

- **Number of fabrics**: If the number of fabrics is likely to increase, then deploy backbone fabrics to readily accommodate additional edge fabrics and additional traffic loads.
- **Size of fabrics**: If the size of edge fabrics is likely to grow, and the inter-fabric traffic is expected to grow accordingly, provision additional IFLs and ISLs such that the capacity of available paths stays well ahead of current usage. That way, incremental growth on the edge can be accommodated without immediately upgrading the backbone.
- **Amount of traffic between fabrics**: If the inter-fabric traffic is expected to grow even without growth in the individual edge fabrics, then provision additional IFLs and ISLs such that the capacity of available paths stays ahead of current usage. That way, incremental increases in data flow across the backbone can be accommodated without immediately upgrading the backbone. Make sure that you allow for plenty of room for backbone expansion.

NOTE: Refer to the *Brocade SAN Scalability Guidelines* for FCR scalability limits.

Consider using FCR under the following conditions:

- There are requirements for added scalability.
- There are benefits to compartmentalizing manageability.
- Enhanced security is required.
- There is a limited number of initiator-target pairs shared between edge fabrics.
- There is a limited number of LUNs shared between edge fabrics.
- Archiving devices, such as tape libraries, must be shared.

The implementation and configuration of inter-fabric links (IFLs in the case of FCR) should be based on the expected data volume between the backbone and edge fabrics and the desired level of redundancy. Some architectural examples of FCR topologies follow.

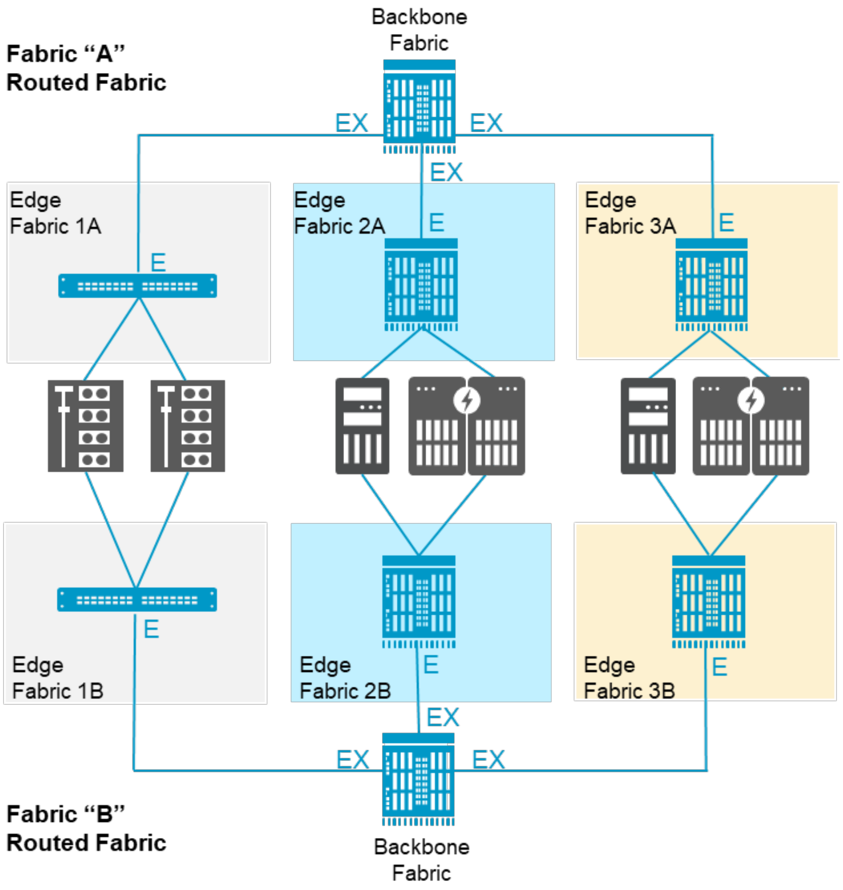
Except in the case of tape, which often has only a single pathway, there should always be A and B fabrics, each with IFL redundancy. A routed fabric environment consists of one or more edge fabrics interconnected by one or more backbone fabrics. Multiple backbone fabrics are parallel and belong to only the A or B fabric, not both. A backbone fabric can be a single switch, multiple switches, or a core-edge topology. These topologies are valid for the edge fabrics as well.

In Figure 12, the architecture consists of three edge fabrics and a backbone fabric. A and B fabrics are shown. The *A* backbone connects to each edge fabric through EX_Ports. EX_Ports in the backbone connect to E_Ports in the edge fabric to form IFLs. Each backbone must have a unique backbone fabric ID (BBFID), and all switches within that backbone must have that same BBFID. The default is 128, and when a single backbone is deployed, as in Figure 12, no BBFID needs to be configured because the default will suffice. An alias can be assigned to BBFIDs.

Each edge fabric must have a unique edge-fabric ID (EFID), and all EX_Port connections to that edge fabric must use that EFID. Each EX_Port is configured with the corresponding EFID belonging to the edge fabric that it connects. E_Ports are not configured with any additional parameters when connecting to EX_Ports.

A collapsed-core backbone is a relatively straightforward FCR architecture.

Figure 12: Routed A and B Fabric Collapsed-Core Architecture



In Figure 13, a separate backbone fabric is not deployed. Instead, the middle fabric is assigned as the backbone, and end devices connect directly to the backbone. There are three fabrics, each with its own self-contained fabric services.

Not having a separate backbone fabric limits the topology from being an interconnected full-mesh. There are only two connections coming out from the center edge fabric, and there is no connection between the left and right edge fabrics. Such a design violates the previously mentioned supported FCR architectures by creating a situation in which more than one EX_Port might be traversed from inside an FC router to the ultimate destination device.

This design might be used when the cost of an additional fabric for the backbone is prohibitive.

Figure 13: Common-Backbone, Dual Collapsed-Core Architecture

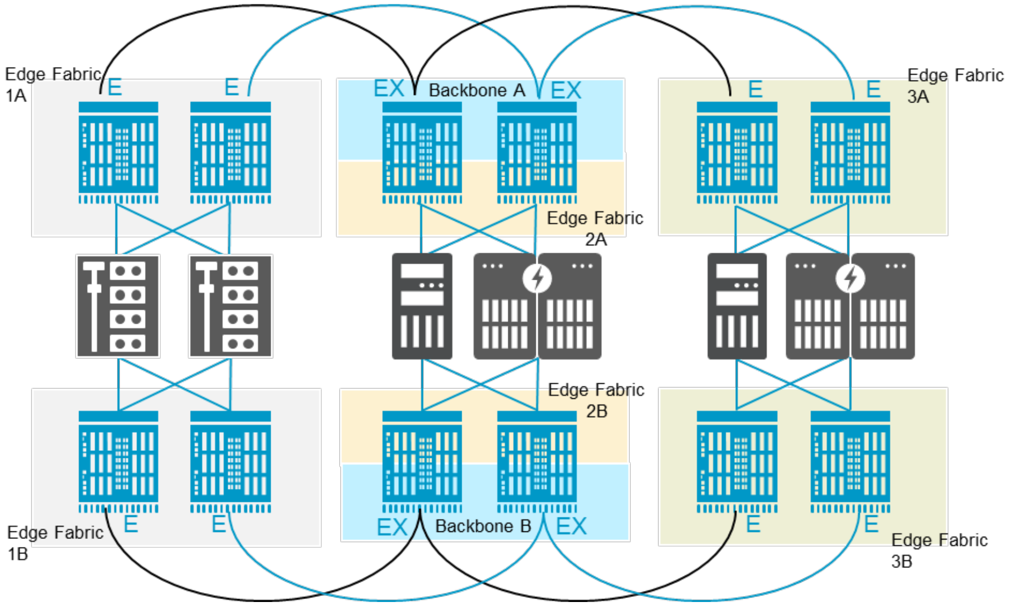
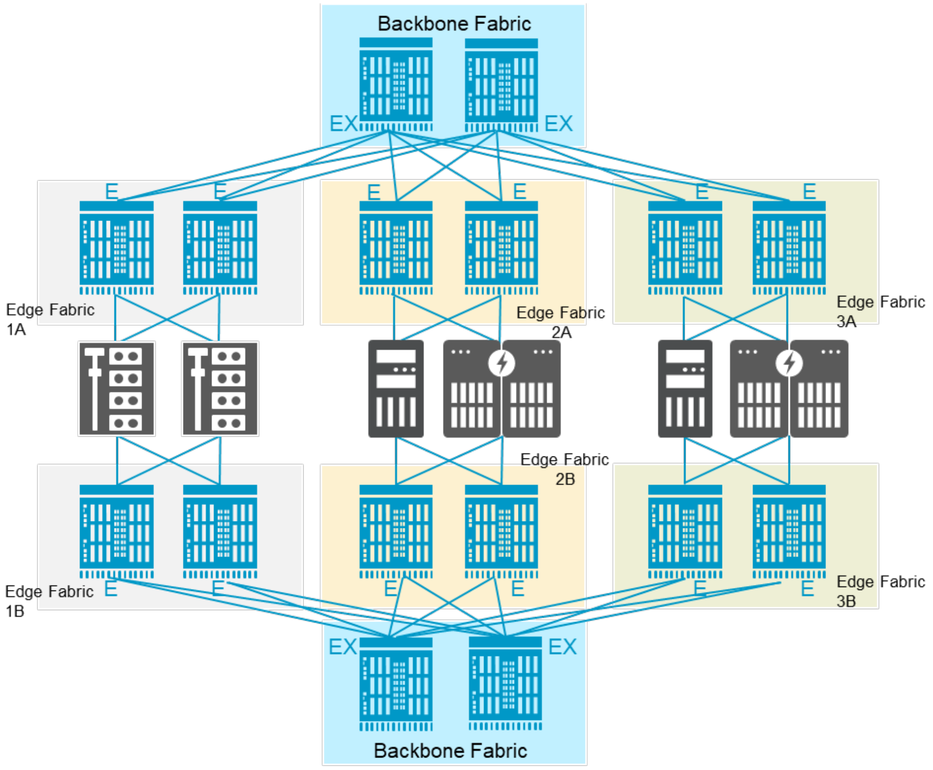


Figure 14 shows a routed SAN with A and B fabrics, each having a dual-core backbone and a unique BBFID. The EX_Ports are exclusively in the backbone, and fabric services do not pass beyond the EX_Ports. There are three edge fabrics, each with its own EFID. There are multiple IFLs to each edge fabric. The dual-core backbone architecture is highly redundant, resilient, and scalable for critical enterprise applications demanding zero downtime. Considering the dual-core backbone's scalability, it is relatively easy to manage operationally.

Figure 14: Dual-Core Backbone Routed Fabric



9.5 Redundancy

Consider the following steps to achieve FCR SAN redundancy:

- Using best practices within the edge fabrics (core-edge or collapsed-core architectures).
- Using best practices within the backbone fabrics (core-edge or collapsed-core architectures).
- Deploying dual backbone fabrics for each fabric (A and B). The need for redundancy versus cost and operations must be considered. Ask yourself what the purpose of the routed SAN is? What happens if routing between edge fabrics goes offline, yet the edge fabrics themselves remain online?
- Parallel IFLs between the backbone and edge fabrics, including ports, optics, and cable redundancy.

9.6 Avoiding Congestion

Bandwidth and potential utilization between endpoints must be evaluated similar to any traditional fabric, by calculating traffic flows in and out of every edge fabric and providing enough backbone bandwidth. For improved utilization and resiliency, the same best practice ISL guidelines are used to connect edge fabrics with IFLs. Higher-performance edge fabrics versus an underperforming backbone can result in an oversubscribed backbone, leading to congestion, higher latency, and longer storage response times during peak loads. If the edge fabric has 64G FC ISLs, the backbone fabric must also have 64G FC ISLs. Before upgrading an edge fabric, upgrade the backbone to avoid congestion and oversubscription issues.

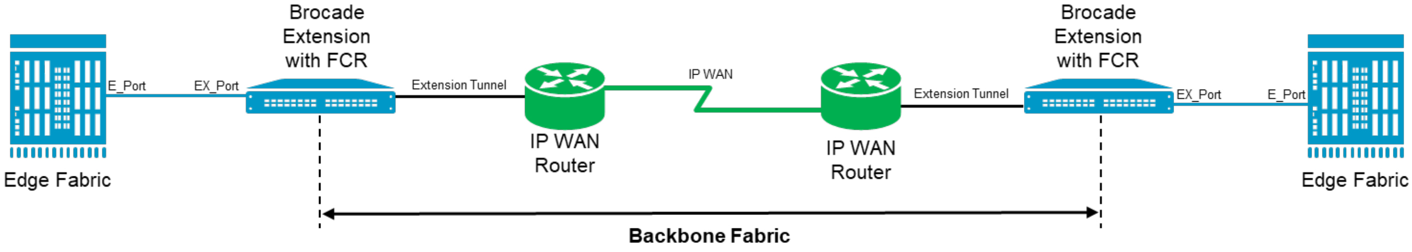
9.7 Available Paths

An optimal approach is to have multiple BT paths between edge fabrics to spread traffic across available resources. Never attach both A and B fabrics to the same backbone device. Connecting A and B edge fabrics to the same backbone device destroys the air gap between A and B and is *not* considered a redundant architecture and best practice. From the perspective of FC, you should adhere to the concept of an air gap from host to storage. A common device connected to A and B fabrics can cause a SAN-wide outage. If an air gap is implemented, faults on one fabric cannot affect the other fabric. These faults can manifest from defects in hosts, drivers, the fabric operating system, the fabric hardware, the storage hardware, the storage software, and human error. It is not relevant that FCR keeps fabric services separate because faults within one large routed fabric can transcend FCR, causing the entire SAN to fail.

9.8 FCR and Extension

FCR can be used within a single data center, across campus data centers, and between edge fabrics connected by FCIP over a metropolitan area network (MAN) or wide-area network (WAN), as shown in Figure 15. A Brocade Extension tunnel is an ISL (VE_Port to VE_Port). A VE_Port is an E_Port that is an endpoint of an Extension tunnel. Each Extension platform becomes part of the backbone fabric. EX_Ports on the Extension platforms connect to the edge fabrics through one or more IFLs.

Figure 15: Fibre Channel Routed Fabric over Extension



More information about Extension can be found in Chapter 12.

9.9 FCR Design Guidelines and Constraints

The following items are some of the key metrics and best practices for routed SAN topologies:

- Keep A and B fabrics separated from host HBA to storage ports from an FC perspective, this separation is referred to as an air gap. Air gaps do not include FCIP because, in an IP network, Ethernet switches and IP routers do not merge as FC fabrics do. Extension VE_Ports should never connect fabric A to fabric B. This connection is the same as cross-connecting a traditional ISL, which connects fabric A to fabric B.
- Localize traffic within an edge fabric to the greatest extent possible.
- Have a predefined schema for assigning domains within the SAN. For example, edges, cores, switches, EFIDs, translate domains, and BBFIDs should be within specific ranges to avoid domain overlap.
- Consider upgrading backbone fabrics before upgrading edge fabrics to avoid oversubscription and congestion.
- During regular operation, have no more than one long-distance ISL or extension tunnel between the source and destination. During an outage, an additional hop might be used for high availability. In a triangle architecture where the primary link is down, the remaining legs can be used as the backup path; however, latency and response times might be longer.
- Long-distance links are within the backbone, not between an edge fabric and the backbone. Edge fabrics are isolated from disruption because fabric services are not extended beyond an EX_Port. Most often, long-distance links are the primary cause of instability.
- Logical SAN (LSAN) zones are only for end devices communicating from edge fabric to edge fabric across a backbone. In other words, do not make zones within edge-fabric LSAN zones.
- For each fabric, fully redundant backbones improve resiliency. Fabric A would not be impacted if one of its backbones failed, the same with fabric B. Both fabric A backbones must fail before fabric B is entirely relied on to maintain operations.
- Redundant backbone fabrics connected to the same edge fabric must have unique BBFIDs. Refer to the case where there is redundant fabric A backbones and redundant fabric B backbones. There are no cross-connections between A and B fabrics, nor are there cross-connections between the parallel backbones within fabric A or B.

Chapter 10: Virtual Fabrics

Virtual Fabrics (VF) is an architecture to virtualize hardware boundaries within a platform. Traditionally, fabric design and management are done at the granularity of a physical switch. VF allow fabric design and management to be done at the granularity of a port.

VF is a suite of related features to customize logical fabrics based on requirements. VF consist of the following specific features:

- Logical switches
- Logical fabrics
- Device sharing

Hardware-level fabric isolation is accomplished through VF, which partitions ports into one or more logical switches. ISL-connected logical switches form logical fabrics. As port density grows, switch partitioning enables storage administrators to divide physical switches into multiple logical switches. Without VF, a FC switch is limited to 512 ports.

There are three ways to connect logical switches: a traditional ISL, an extension ISL, an IFL (EX_Port used by FCR), or an extended ISL (xISL). An ISL is used for regular FC traffic between logical switches. An ISL carries data traffic within the logical fabric of which the ISL is a member. An advantage of VF is that multiple logical switches can share a common physical ISL, called an xISL. Each logical switch does not require a dedicated ISL (DISL). For multiple logical fabrics to share an ISL, Virtual Fabrics supports xISL connections. An xISL is a physical connection between two base switches. Base switches connected by an xISL form a base fabric. A base switch is a logical switch used for intra-fabric and inter-fabric communication.

Once a base fabric is formed, VF determines the best route between all associated logical switches and logical fabrics. For each local logical switch and every destination reachable through the base fabric, a logical ISL (LISL) is created. Thus, an xISL is a physical link between base switches, carrying virtual connections. In addition to xISLs, a base fabric supports EX_Ports for communication between logical fabrics. An FCR link between an EX_Port and an E_Port is called an IFL. Base switches interoperate with FCR through EX_Ports in the base fabric or EX_Ports in a different backbone fabric.

10.1 Use Case: FICON and Open Systems (Intermix)

VF enables customers to share FICON and FCP (SCSI and NVMe) traffic on the same physical platform. As chassis densities increase, this is a viable option for improved hardware utilization while maintaining director-class availability. The following items are the primary reasons for moving to an Intermix environment:

- Array-to-array RDR of FICON volumes (Most array replication uses FCP for FICON volumes.)
- ESCON-FICON migration
- Sharing of infrastructure in a nonproduction environment
- Reduced TCO
- Growth of zLinux on the mainframe

From a SAN design perspective, consider the following guidelines when considering FICON Intermix:

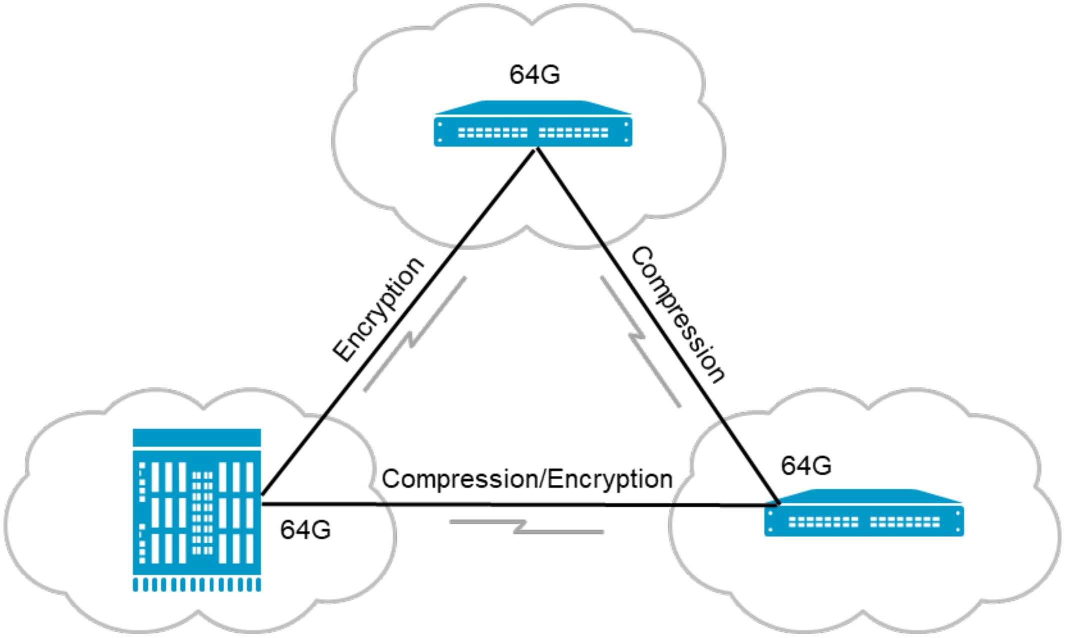
- Connect devices across port blades (connectivity from the same device should be spread over multiple blades).
- A one-hop-count architecture applies; however, there are *hops of no concern* in some cases. Refer to the *Brocade FICON/FCP Intermix Best Practices Guide* for details.

Chapter 11: Fibre Channel Intelligent Services

11.1 In-flight Encryption and Compression

Brocade Gen 6 and Gen 7 Fibre Channel platforms support both in-flight compression and encryption at the port level for local and long-distance ISL links (see Figure 16). In-flight data compression is a valuable tool for saving money when bandwidth caps or bandwidth usage charges encumber transferring data between fabrics. Similarly, in-flight encryption enables additional security when transferring data between local and long-distance data centers.

Figure 16: Latency for Encryption and Compression



As the frame is processed, enabling in-flight ISL data compression or encryption increases ASIC latency. At each stage (including encryption, compression, and local switching), the approximate latency is 6.2 microseconds (see Figure 16).

11.1.1 Virtual Fabric Considerations: Encryption and Compression

E_Ports in logical switches, base switches, or default switches can support encryption and compression. Both encryption and compression are supported on xISL ports but not on LISL ports. If encryption or compression is enabled and ports are moved from one LS to another LS, it must be disabled before moving to another LS.

11.1.2 Guidelines: In-Flight Encryption and Compression

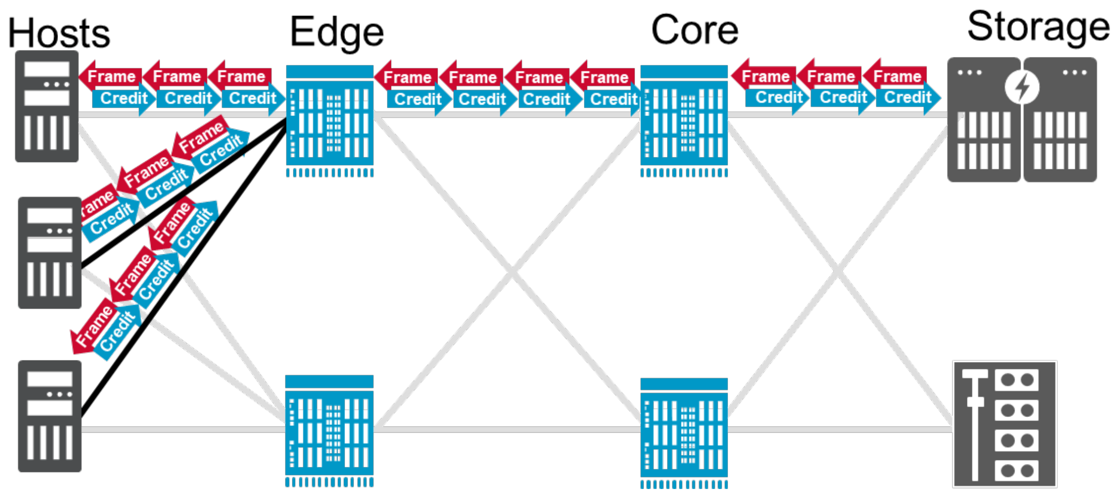
Refer to the *Brocade Fabric OS Administration Guide* for the latest information.

11.2 Fabric Notifications

Fibre Channel networks can be elusive to troubleshoot because flows are difficult to visualize, and the affected devices are not likely to correspond with the problem cause. Fibre Channel uses a credit-based flow-control mechanism (see Figure 17), with inherent congestion characteristics due to head-of-line blocking. Broadcom introduces a hardware, software, and management solution called Fabric Notifications for achieving congestion reduction and elimination.

Collecting transport characteristic data from various sources, evaluating it, and disseminating it to interested devices allows for faster and sometimes automatic problem resolution. End devices can employ primary response and recovery mechanisms. Fabric information is helpful for end devices, and end devices have helpful information for the fabric and peer end devices. Fabric Notifications are crucial in collecting and disseminating information among related and interested devices.

Figure 17: Freely Moving Lossless Credit-Based Flow-Control FC Network



Fabric Notifications addresses four issues: congestion (oversubscription and credit stall), link integrity, and SCSI command delivery failure.

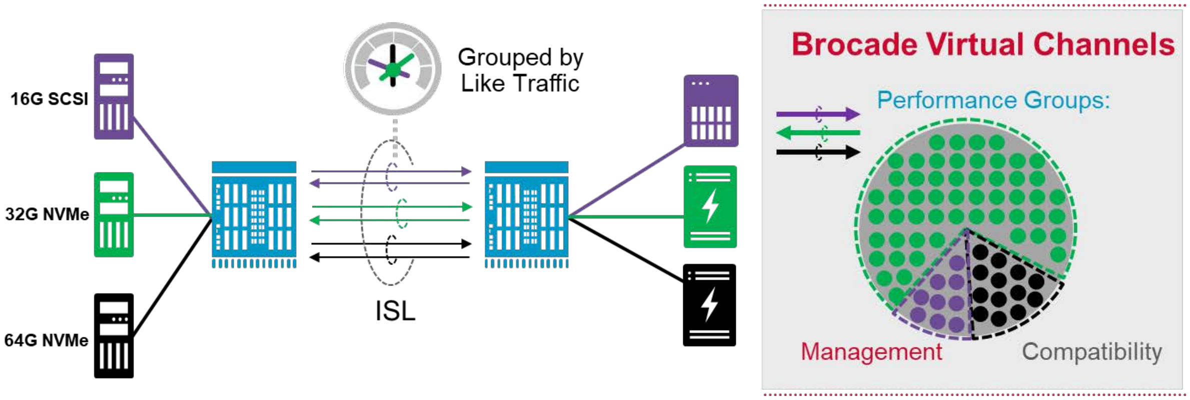
11.3 Traffic Optimizer

For years, Brocade VCs worked perfectly well at 1, 2, 4, 8, and 16-gigabit rates by leveraging multiple logically independent paths. To a degree, virtual channels mitigated interference between slower flows impeding faster flows. Optionally, critical faster flows could be manually assigned to a high QoS VC, and slower flows could be manually assigned to a low QoS VC to prevent such interference.

Technology evolves, and Broadcom has optimized VC efficiency by enhancing effectiveness to targeted flow characteristics. Demands on an enterprise SAN have never been more significant due to other complimentary technology evolutions such as NVMe, AFA, and host virtualization. Flows compete for resources, and head of line blocking is not an option and must be efficaciously dealt with, which is where Traffic Optimizer helps.

Brocade Traffic Optimizer technology takes VCs to the next level (see Figure 18). Traffic Optimizer organizes and manages traffic flows using performance groups (PGs), and fabric resources are allocated based on performance groups. Flows are assigned to a VC based on the destination port speed and protocol (SCSI or NVMe). Brocade fabrics know the destination port speed and protocol for every flow.

Figure 18: Host to Storage through Traffic Optimizer VCs



Brocade Gen 7 hardware added more VCs. E_Ports and EX_Ports use 16 new Traffic Optimization VCs, which are assigned as follows: Four VCs per speed (<16, 32, 64) for a total of 12 VCs, plus four VCs dedicated to NVMe. Benefiting from an NVMe storage investment requires NVMe dedicated resources in the SAN.

QoS VCs have not changed: there are two for low, four for medium (default), and five for high. QoS VCs are used when traffic has been designated to a high or low priority. SDDQ uses the QoS low VCs.

Chapter 12: Extension

The extension content has been removed from this document. Extension is a considerable subject, and a separate extension document exists. The content from this Chapter was added to and will be managed in the extension document. Please refer to the document: *Design Guide: Brocade Extension Best Practices*

Chapter 13: SAN Design for Critical Workloads

All-flash arrays (AFA) are the technology standard in enterprise data centers. As transitioning to FC-NVMe is underway, critical business applications increasingly depend on consistent low-latency, high-throughput storage performance for demanding performance-sensitive workloads. When designing a SAN, it is vital to consider the placement of critical workloads relative to storage, the fan-in ratio to storage ports, and BTs.

Protecting critical workloads is crucial. Brocade technology provides measures such as Traffic Optimizer, FPIN, MAPS, and SDDQ to avoid workload interference that might experience congestive behavior. Ideally, the most demanding and critical workloads have dedicated storage ports, maybe a dedicated array, and the shortest possible path through the fabric. The purpose is to avoid other workload interference resulting in congestion or backpressure, which could adversely impact the performance of critical applications.

13.1 Placement of Servers with Business-Critical Workloads

With core-edge SAN designs, connecting critical workload servers directly to the core alongside the storage ports is often advantageous. This practice works well when the number of business-critical workloads is easily defined and limited to a subset of servers, and an adequate number of core ports are available.

Suppose the number of business-critical servers exceeds the number of available ports on the core; in that case, connecting the business-critical servers to the edge switches is necessary. The most common model uses dedicated edge switches for business-critical servers to remove competing flows and decrease the fan-in ratio of servers to ISLs.

An alternative is to evenly distribute business-critical servers across the edge switches, assuming that workloads even out with other less demanding workloads. Although a logical approach, the practice has demonstrated that using this model is operationally complex to guarantee optimal performance for business-critical workloads.

13.2 Business-Critical VMs

In today’s data centers, it is common for business-critical workloads to run on VMs. Combining this with a digital society, the value, criticality, and performance requirements for a given application change throughout the application’s life. Inevitable change means predicting future requirements can be difficult or impossible. Placement planning from the beginning is not simple—luckily, hypervisors can relocate VMs without disruption and migrate storage when necessary. The same principle applies to bare metal server placement, deploying dedicated hypervisor clusters connected to the core or high-performance edge switches.

VM Insight provides visibility into each VM’s workload, even on the same datastore. It enables storage administrators to monitor VM-level application performance and set baseline workload behavior. This information determines whether the SAN is the source of performance anomalies. Storage administrators can plan placement and provision based on application requirements and fine-tune infrastructure to meet service-level objectives.

Chapter 14: Access Gateway and NPIV

This chapter covers Access Gateway (AG) and N_Port ID Virtualization (NPIV) design considerations, primarily related to increasing fabric density and scale. In addition, there are descriptions for AG default port mapping, port mapping for specific architectures, ensuring balance and failover, and best practices.

Refer to the *Brocade Fabric OS Access Gateway User Guide* for detailed information on configuring and deploying AG.

Standards-based NPIV connects multiple virtual F_Ports to a single physical N_Port. These virtual F_Ports connect multiple host initiators, such as a hypervisor with virtual HBAs or a storage device with multiple virtual targets, to a physical HBA port. NPIV was initially developed to provide access to FC devices from IBM mainframes and improve the efficiency of mainframe I/O for virtualized environments.

A use case is a switch configured in NPIV mode and connected as an Access Gateway to the fabric. AG does not participate in the fabric as a domain; it extends fabric ports without adding a domain. A switch in NPIV mode is a way to connect another vendor's switch. Broadcom supports connecting other standards-based switches in NPIV mode.

The following items are common NPIV use cases:

- Using AG to increase port count without increasing domains
- Deploying AG in a POD architecture
- Connecting many embedded switches that are in blade-server chassis
- Connecting other vendor switches (Cisco UCS FI)
- Creating storage arrays with a virtual storage controller architecture that presents separate virtual target ports behind the same physical target port
- Provisioning hypervisors with virtual HBAs to VMs for Raw Device Mapping (RDM) storage allocation

As shown in the following figure, a switch in AG mode connects F_Ports to the fabric as N_Ports instead of E_Ports. Figure 19 shows a switch in native mode with all devices connecting to F_Ports and switch-to-switch connections as E_Ports (ISLs).

Figure 19: Switch Functioning in Native Mode

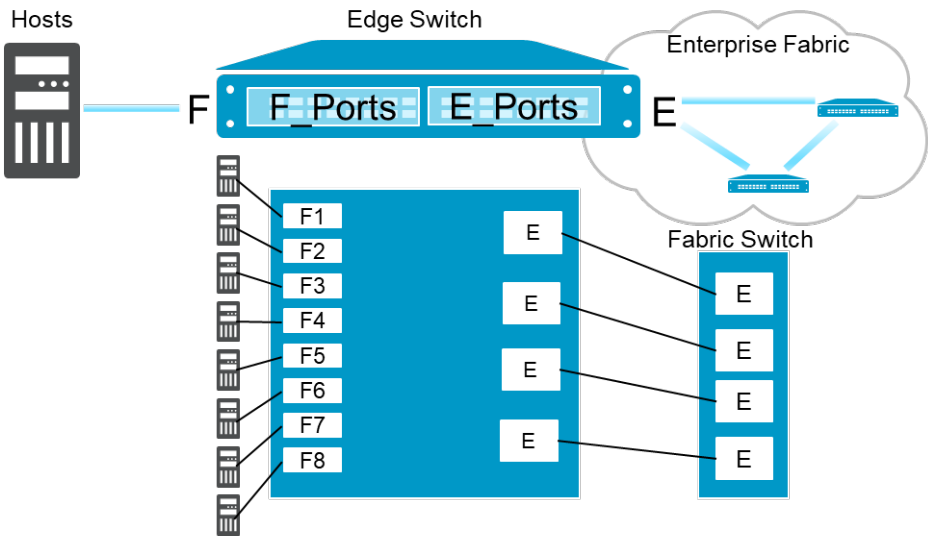
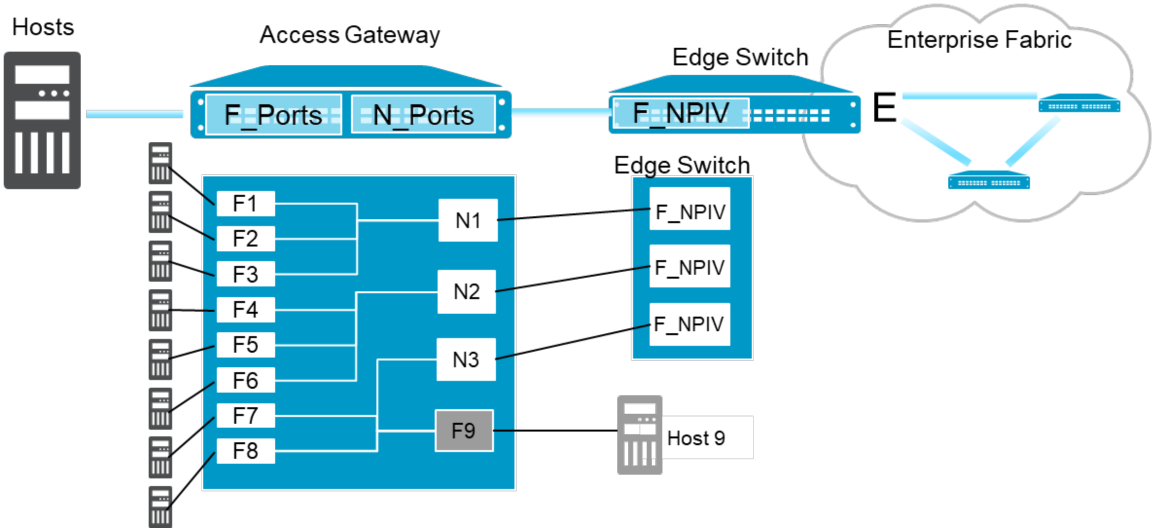


Figure 20 shows a switch in AG mode with all devices connecting to F_Ports, then mapping to N_Ports. The AG N_Ports connect to the fabric's NPIV F_Ports, typically on an edge switch.

Figure 20: Switch Functioning in Access Gateway Mode



Switches in AG mode are transparent to the host and fabric. The hosts accessing the fabric can be increased without increasing domains. AG mode simplifies configuration and management by reducing the number of domains. Fabric-specific configuration is inherited on fabric switches; for example, zoning. AG does not participate in these fabric services.

Placing switches in AG mode does not consume a fabric domain ID. The main reason for using AG mode is to achieve scalability with many small switches. The embedded switches can quickly approach the maximum domain limit in a blade server environment.

AG functionality is enriched, although there are scenarios in which full switch functionality is advantageous. Deciding to use AG involves evaluating whether AG is an appropriate option. Identifying and isolating misbehaving devices in a fabric with many legacy devices is easier in a complete switch environment.

For configurations with hosts and targets connected to the same AG, traffic must first pass through the AG to a fabric switch. If AG is not used, local traffic is switched by the embedded switch and does not need to traverse the AG to the fabric and back. The theoretical domain limit in a fabric is 239, but most fabrics are limited to a much smaller number. The maximum number of domains supported in Brocade fabrics is 56. The domain count limit comes into play when many small-port-count switches are deployed. Large blade-server deployments with embedded switches push the domain count beyond supported limits. FC switches in blade server enclosures typically represent fewer than 32 ports.

14.1 Benefits of Brocade AG

- **Scalability:** AGs can be added to a fabric without increasing domain count. A scalability constraint is avoided when small-port-count switches and embedded switches are part of the infrastructure. Registered state change notifications (RSCN) are reduced; only downstream initiators on the AG are passed to the fabric. AG upstream ports can connect to one or more fabrics. AG cascading is supported and reduces the fabric connections required to support attached hosts.
- **Error isolation and management:** Most initiator errors do not propagate through the fabric. Management activities on AG are isolated from the fabric. Disconnecting an upstream port does not cause a fabric event. Blade-server administrators manage AG. Storage administrators using NPIV, provision LUNs, and support zoning.

- **Increased resiliency:** AG supports F_Port trunking, which increases upstream resiliency to the fabric. Losing an optic, link, or cable simply reduces the bandwidth of the trunk. A few frames might be lost; however, no host connections are affected.
- **Other:** Hosts or HBAs can be configured to failover to another upstream link automatically should the link being used fail. AG implements advanced features such as adaptive networking, BT, HCL (hot code load), MAPS, ClearLink Diagnostics (D_Port), credit recovery, and FEC.

14.2 Constraints

The advantages of the Brocade Access Gateway are compelling, but there are constraints:

- Although the benefits are much more evident for servers, AG supports storage devices, but the traffic must flow through to the fabric, which has limitations.
- The maximum NPIV connections per upstream port is 254.
- The maximum AG per switch is limited by the number of connections the fabric switch supports.

Primary factors to consider:

- The number of devices that attach to the fabric through AG
- The number of devices per AG N_Port
- The number of devices attached to the switch and fabric

Refer to the *Brocade SAN Scalability Guidelines* for details.

The number of fabrics an AG can be connected to is limited by the number of N_Ports on the AG. Most deployments require two AG connections to each fabric. Note that connecting different upstream ports to different fabrics does not reduce the requirement for redundancy. All attached servers should have dual paths to storage through different fabrics and separate AG.

14.3 Design Guidelines

Use AG to deploy blade servers, many low port-count switches, or connect blade enclosures to multiple fabrics. AG separates blade enclosure management, so server administrators manage the enclosure, and storage administrators manage the fabric. Flow separation is provided through NPIV, allowing AG to be managed separately. Integrated blade-server management tools pose no risk to fabric operations.

14.4 Monitoring

Brocade Access Gateway has been enhanced to include features found in the standard version of Brocade FOS, such as Port Fencing, device security policies, FPI monitoring, and SDDQ. However, monitoring and troubleshooting NPIV flows are less feature-rich than traditional flows.

14.5 Maintenance

Maintaining AG firmware levels synchronized with fabric firmware levels usually is not required. Broadcom supports other vendors' NPIV-enabled devices where firmware synchronization is not possible. Maintaining firmware levels can be significant in large fabrics with many AGs. The version of Brocade FOS running on fabric switches can be upgraded at one time and AGs at another time, dramatically reducing the amount of change required to the infrastructure during a single maintenance window.

See the *Brocade Fabric OS Release Notes* to determine if a synchronized Brocade FOS upgrade of Brocade Access Gateway devices is required.

14.6 Access Gateway Mapping

When a switch operates in AG mode, you must specify the AG device's routes to direct traffic from the devices on its F_Ports to the fabric ports connected to its N_Ports. The routes must be preprovisioned. The process of provisioning routes in AG mode is called mapping. By comparison, a switch operating in Native mode determines the best routing path between its F_Ports.

You can create two types of maps: port maps and device maps. Port maps are required. Device maps are optional and assign device WWNs to N_Ports and N_Port groups. Port mapping and device mapping operate as follows.

14.6.1 Port Mapping

Port mapping ensures all traffic from a specific F_Port goes through the same N_Port. An F_Port is mapped to an N_Port or N_Port group. To map an F_Port to an N_Port group, map the F_Port to an N_Port belonging to that group.

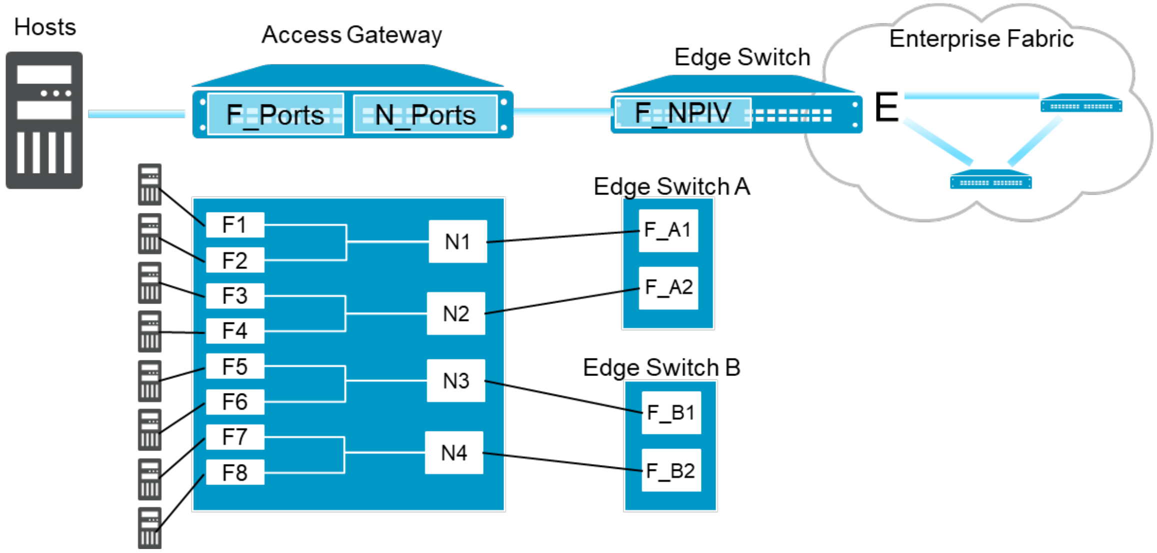
14.6.2 Device Mapping

Device mapping is optional. Port maps must exist before you can create device maps. Device mapping allows a virtual port to access its destination device regardless of the F_Port where the device resides. Device mapping also allows multiple virtual ports on a single physical machine to access multiple destinations in different fabrics. You can map a device to multiple groups. Alternatively, you can map a device to a specific N_Port.

The preferred method is to map a device WWN to an N_Port group. When a WWN is mapped to a port group, it can log in to the fabric if at least one N_Port remains online. However, when a WWN is mapped to an N_Port and a failover N_Port is specified, the WWN can only reach the fabric through the primary and failover N_Ports.

F_Ports must be mapped to N_Ports before the F_Ports can come online.Figure 21 shows an example in which eight F_Ports are mapped evenly to four N_Ports on a switch in AG mode. The N_Ports connect to the same fabric through different edge switches.

Figure 21: Port Mapping Example



The following table shows the port mapping illustrated in the figure. F_Ports F1 and F2 map to N_Port N1; F_Ports F3 and F4 map to N_Port N2, and so forth.

Table 1: Description of Port Mapping

Access Gateway		**Fabric**	
F_Port	N_Port	Edge Switch	F_Port
F1, F2	N1	Switch A	F_A1
F3, F4	N2	Switch A	F_A2
F5, F6	N3	Switch B	F_B1
F7, F8	N4	Switch B	F_B2

14.6.3 Default Port Mapping

When you enable AG mode on a switch, a default mapping is used for the F_Ports and N_Ports.

The following table describes the default port mapping for a G720. Refer to the *Brocade Fabric OS Access Gateway User Guide* for default mappings on all supported hardware platforms.

Table 2: Access Gateway Default Port Mapping for a G720

Brocade Platform	Total Ports	F_Ports	N_Ports	Default Port Mapping
G720	64	0-39, 48-63	40-47	0-6 mapped to 40 7-13 mapped to 41 14-20 mapped to 42 21-27 mapped to 43 28-34 mapped to 44 35-39, 48-49 mapped to 45 50-56 mapped to 46 57-63 mapped to 47

NOTE: By default, failover and failback policies are enabled on all N_Ports.

The default mapping can be changed to meet specific requirements for your environment. For more information, refer to the *Brocade Fabric OS Access Gateway User Guide*.

Chapter 15: Security

Many SAN security components are related to design, and deciding to use them depends on requirements rather than network functionality or performance. When designing SAN security, it is optional to implement security features. Some security features add performance overhead, others affect administrator productivity, and others have associated implementation costs. There is a balance between features, the value of protecting assets, and the chance of exploiting a vulnerability.

One clear exception is the zoning feature used to control device communication. Proper zoning is vital to fabric functionality, performance, and stability, especially in more extensive networks. Other security-related features are mechanisms for limiting access and preventing attacks on the network, often mandated by regulatory requirements and not required for operation.

This chapter covers best practices for secure SAN communication and secure SAN infrastructure access and protection.

15.1 Zoning: Controlling Device Communication

Brocade zoning is crucial in managing device communication, essential for effective, efficient, and secure storage network use. The SAN is responsible for data flow between devices, and zoning specifies which device can communicate with another. Zoning is enforced, disallowing communication between devices not within the same zone.

Zoning protects devices from disruption by constraining the RSCN scope. Fabric changes generate notifications (RSCNs) to the fabric and end devices. Delivery is limited to devices in the zone and only when a change occurs. This limit reduces switch processing overhead by reducing RSCNs and, in rare cases, limits the impact of a faulty HBA that creates errors. Thus, only devices in the zones impacted by a change are disrupted. Based on this, the best practice is to create single-initiator single-target zones with one initiator and one target so that changes to initiators or targets do not impact other initiators and targets. Disruptions are minimized, as shown in Figure 22. In addition, the default zone setting should be *No Access*, devices are isolated when zoning is disabled.

Zones can be defined by either the device's connected switch port or the device's Port World Wide Name (pWWN). Although it takes more effort to use WWNs in zoning, it provides excellent flexibility. For example, moving a device anywhere in the fabric maintains a valid zone.

15.1.1 Peer Zoning

As the number of hosts increases, configuring and maintaining single-initiator zones becomes challenging. Additionally, a unique zone for each initiator and target could grow to exceed the maximum zone database size.

Many-to-one zoning defines many initiators with one target. Before the availability of peer zoning, it was common to zone multiple initiators with a single target to achieve provisioning efficiency; by today's standards, this is not a best practice.

Peer zoning is easier to manage and avoids exceeding the maximum database size; conversely, peer zoning results in increased RSCN traffic. A SAN using peer zoning provides operational efficiency and effective single-initiator zoning while reducing the database size.

Peer zoning allows a principal device to communicate with non-principal devices within the zone as a single-initiator, single-target zone. Non-principal devices can communicate only with the principal device; they cannot communicate with each other. Principal devices cannot communicate with other principal devices.

A peer zone can have one or multiple principals. In general, storage ports are assigned as principals. Multiple principal members in a peer zone are used when all the non-principals (initiators) in the zone are to share the same target (storage) ports.

The peer zone members are WWNs or aliases specifying WWNs or domain, port. You cannot mix WWNs and domain, port or associated aliases when defining peer zoning.

15.1.2 Target-Driven Zoning

Target-driven zoning is a variant of peer zoning; the user specifies the configuration in a regular peer zone, and the principal device defines the target-driven zone. The principal device is usually a storage array, but it does not have to be. Target-driven zoning must be enabled on the F_Port connected to the principal device. Target-driven zoning uses a third-party interface to manage the device and switch interactions.

Refer to the vendor's principal device manual to determine the commands and options to construct a target-driven peer zone.

Refer to the applicable *Brocade Fabric OS Administration Guide* for additional details and considerations.

15.1.3 Zone Management: Duplicate WWNs

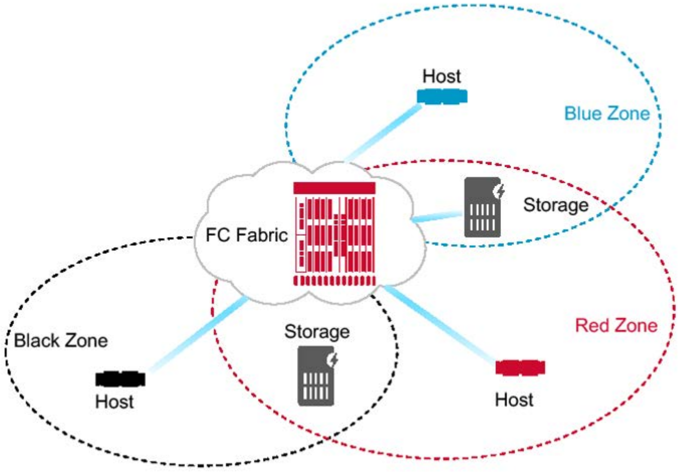
In a virtual environment like VMware or HP's Virtual Connect, it is possible to encounter duplicate WWNs in the fabric, often as a transient condition. Duplicate WWNs impact switch responses to fabric service requests such as *get port WWN*, which results in unpredictable behavior. Additionally, it represents a security risk by enabling spoofing of the intended target. The fabric's handling of duplicate WWNs is not meant to be an intrusion detection tool but rather a recovery mechanism. When a duplicate entry is detected, a warning message is sent to the RASlog, and no effort is made to prevent the device login of the second entry.

The handling of duplicate WWNs is as follows:

- Same switch: The choice of which device stays in the fabric is configurable. The default is to retain the current device.
- Same WWN on two switches: remove both entries.
- Zoning recommendations include the following:
  - Always enable zoning
  - Use peer zoning or single-initiator zoning
  - Define zones using device World Wide Port Names (WWPN or pWWN)
  - Set default zoning to No Access

Follow the vendor guidelines for preventing the generation of duplicate WWNs in a virtual environment.

Figure 22: Example of Single-Initiator to Single-Target Zones



15.2 Securing the SAN Infrastructure

An operational advantage of a Brocade SAN is quickly adding new switches to a fabric. A SAN administrator need only connect a new switch to an available port on an existing switch through an ISL and then power up the new switch. A unique domain ID is automatically assigned, and the configuration files are downloaded to the new switch. However, from a security perspective, this time-saving administrative ease-of-use capability also means that anyone with a switch and physical access could connect to an existing fabric and gain control. If an attacker with admin access on a rogue switch were to use this technique, the attacker would now have admin privileges for the entire fabric.

There are several layers of defense available to secure the SAN. In order of ease of deployment, the following list describes best practice configurations to secure the SAN. Deploy the first four layers. Deploy the remaining layers depending on the organization’s security requirements.

The security defense layers in the order of deployment ease:

- Persistently disable unused ports
- Prevent switch ports from becoming E_Ports
- Configure auditing
- Use a strict fabric-wide consistency policy where possible
- Use the SCC policy to restrict switch connections to the fabric
- Use an FCS policy to restrict security configuration changes further
- Use DCC policies to restrict device access by WWN and physical switch ports
- For more sensitive environments, use DH-CHAP to authenticate devices that join a fabric

The first and simplest line of defense is to persistently disable all unused ports, which can prevent someone without administrative privileges from connecting to the fabric. It is vital to use the persistent disable option to ensure that disabled ports remain disabled after a reboot or power cycle. Otherwise, an attacker could unplug the switch to re-enable unused ports.

The second line of defense is to prevent ports from becoming E_Ports. If an unused port remains enabled, a new switch would not be able to join the fabric if the port cannot become an E_Port.

The third line of defense is configuring auditing to ensure visibility into any unexpected access, changes, events, and attacks.

The fourth line of defense is to use a fabric-wide consistency policy to ensure that all fabric switches avoid a *weak link* exploitable attack.

Subsequent layers use an access control list defense, described in more detail in the following section.

Implementing all lines of defense is often unnecessary. The layers implemented depend on an organization's requirements, data sensitivity, environment, and risk tolerance. In practice, only some organizations implement all levels. It is up to each organization to establish the acceptable risk and decide which features should become part of operations.

15.3 Access Control Lists

Access control lists (ACLs) provide network security through policy sets. Brocade FOS provides several ACL policies, including a Switch Connection Control (SCC) policy, a Fabric Configuration Server (FCS) policy, a Device Connection Control (DCC) policy, an IP Filter policy, and others. The following subsections briefly describe each policy and provide basic guidelines.

A more in-depth discussion of ACLs can be found in the *Brocade Fabric OS Administration Guide*.

15.3.1 SCC Policy

The SCC policy restricts fabric elements from joining a fabric, particularly Brocade FOS platforms. Only switches specified in the policy are allowed to join the fabric. All other attempts to join will fail authentication, resulting in the E_Ports being segmented due to a security violation.

Use the SCC policy in environments where there is a need for strict control of fabric members. Since the SCC policy can prevent switches from participating in the fabric, reviewing and adequately maintaining the SCC ACL regularly is essential.

15.3.2 FCS Policy

Use the FCS policy to restrict the source of fabric-wide settings to one FC switch. The policy contains the WWN of one or more switches, and the first online WWN becomes the primary FCS. The primary FCS can make changes and propagate fabric-wide parameters if an FCS policy is active. These parameters include the zoning database and security policies database.

Use the FCS policy in environments that need to strictly control fabric settings. As with other ACL policies, reviewing and adequately maintaining the FCS policy regularly is essential.

15.3.3 DCC Policy

The DCC policy restricts devices through WWN from attaching to an FC port. The DCC policy set comprises the DCC policies defined for each FC port. The policy specifies the FC port and one or more WWNs allowed to connect to that port. Not every FC port needs a DCC policy; only the ports in the active policy set enforce access control. A port in the active DCC policy set allows only the specified WWNs to connect and log in to the fabric. All other WWNs fail authentication when attempting to connect, which results in the corresponding F_Port being disabled due to a security violation.

Use the DCC policy in environments where there is a need for strict control of fabric members. Since the DCC policy can prevent devices from participating in a fabric, it is essential to review and adequately maintain the DCC policy regularly.

15.3.4 Policy Database Distribution

Brocade FOS provides a mechanism for controlling the distribution of the security policy database on a per-switch basis. Switches can use individually configured policies or a fabric-wide distributed policy on each platform. They can accept or reject a policy distributed from another switch. A fabric-wide distribution policy can be defined for SCC and DCC with support for strict, tolerant, and absent modes. The following modes enforce whether the SCC and DCC policy must be consistent throughout the fabric.

- **Strict mode:** All updated and new policies of the type specified (SCC, DCC, or both) must be distributed to all switches in the fabric, and all switches must accept the policy distribution.
- **Tolerant mode:** All updated and new policies of the type specified (SCC, DCC, or both) are distributed to all switches in the fabric, but the policy does not need to be accepted.
- **Absent mode:** Updated and new policies of the type specified (SCC, DCC, or both) are not automatically distributed to other switches in the fabric; policies can be manually distributed.

Together, the policy distribution and fabric-wide consistency settings provide a range of control over the security policies, from no control and little control to strict control.

Refer to the *Brocade Fiber Channel Security Best Practices* for a detailed discussion of SAN security concepts and issues.

15.3.5 Authentication Protocols

Brocade FOS supports both Fibre Channel Authentication Protocols (FCAPs) and Diffie-Hellman Challenge Handshake Authentication Protocols (DH-CHAPs) on E_Ports and F_Ports. Authentication protocols provide additional security during link initialization by assuring that only the desired device/device type connects to a given port.

15.4 Secure SAN Management

User account and role management are cardinal to secure SAN management, with strong policies for accounts and passwords in combination with separation of duties and assigned privileges on a need-to basis only.

The following list outlines best practices for secure SAN management:

- Allow only secure protocols to connect the switches (SSH, HTTPS, and SNMPv3).
- Use unique user accounts with proper roles and privileges.
- Change default passwords on *all* default accounts, and, ideally, do not use default accounts.
- Create and enforce password policies (strength, history, expiration, and lockout).
- Use a centralized account and password management methods such as RADIUS, TACACS+, or LDAP.

15.4.1 Role-Based Access Controls

One way to limit access to a fabric is through user roles. Brocade FOS has predefined user roles, each authorizing a subset of CLI commands. Predefined roles are called Role-Based Access Controls (RBAC) and are associated with user login credentials. RBAC aligns users with their function and authority. Users are granted specific privileges based on an organization's security model to enforce the separation of duties. A role could be read-only, allowing users to view information without modifying or deleting it. A role can grant full admin privileges at the opposite end of the spectrum. Other roles fall in between and can be customized for specific functions, such as an operator or a security administrator.

15.5 Securing Management Interfaces

Management interfaces are a vulnerable point in any IT infrastructure; therefore, protecting them should always be a high priority and reasonably straightforward. The following list outlines the measures to protect the management interfaces:

- Use a separate VLAN (or private VLAN) for the management network
- Use secure protocols to access management interfaces (SSH, HTTPS, and SNMPv3)
- Disable the equivalent non-secure protocols (Telnet, HTTP, and SNMPv1)
- Limit the entry points for management with an IP Filter policy, and use an FCS policy if necessary.

Since malicious insiders can be a threat, protect management interfaces using a separate VLAN and subnet to isolate the management network. An isolated network limits access to SAN administrators, making access from other networks difficult. Use secure protocols to encrypt communications from management workstations to Brocade platforms. Encrypted protocols are SSH, HTTPS, and SNMPv3; disable the equivalent unsecured protocols telnet, HTTP, and SNMPv1.

15.5.1 IP Filter

The IP Filter policy is a set of rules applied to the IP management interfaces as a packet-filtering firewall. According to the IP Filter rules, the firewall permits or denies (drops) the traffic going through the IP management interfaces.

Brocade Fabric OS supports multiple IP Filter policy definitions. IPv4 and IPv6 are the policy types and provide separate packet filtering for each. You cannot specify IPv6 addresses in the IPv4 filter or IPv4 addresses in the IPv6 filter. Up to six filter policies can be defined for each type, and one IP Filter policy can be active for each type.

The IP Filter policy restricts access to the Ethernet management ports. Only the IP addresses listed in the IP Filter policy can connect to the specified TCP/UDP port (if specified). IP Filter rule construction varies.

The IP Filter policy should only allow secure protocols. For stronger security in environments requiring strict access control, the source addresses or subnets for which SAN administration is performed should be the only permitted IP addresses. As with other ACL policies, regularly reviewing and adequately maintaining the IP Filter policy is essential.

Chapter 16: Automation

16.1 Overview and Purpose

Most IT administrators have first-hand experience in managing the growing complexity of enterprise infrastructure. According to a report from the Enterprise Strategy Group, “The cost and complexity of protecting and storing data is increasing, and IT leaders are responding with attempts to better optimize and automate storage—but better tools are needed.”

Broadcom is uniquely positioned to spot and understand the impact of automation, helping organizations get more from their SAN infrastructure. Broadcom offers a combination of SAN automation with RESTful APIs and a SAN management platform to help organizations drive greater efficiency. Automation and efficiency are accomplished through a variety of means:

- Brocade Automation multilayer architecture
- RESTful API support on platforms and management tools
- Broadcom Ansible management framework eliminates repetitive tasks, simplifies management, and orchestrates infrastructure

16.2 Motivation to Automate

The following are five reasons why organizations should embrace SAN automation:

- Reducing human error and streamlining operational processes have never been more crucial. As organizations move to digitize and adapt to new workloads, data availability, processing time, and agility in provisioning on-demand applications become the business’s life-blood. These new digitized workloads demand a more efficient and expedient infrastructure management approach, leaving no room for human error. As a result, storage administrators need to be freed from repetitive manual tasks such as configuration management, reporting, documenting inventory, and troubleshooting. Instead, IT organizations need SAN automation to help them automate and orchestrate repetitive tasks, significantly improve efficiency, and decrease the risk of operational mistakes.
- Demand for more accurate and more frequent infrastructure reports is on the rise. It is not just IT managers who crave information on storage performance, utilization, and forecasting; business stakeholders are also asking for and expecting this data on demand. No one wants to wait for a slot when storage administrators can allocate time to produce a report. This information should be available as frequently as business demands dictate—all at the click of a button. Automation provides this kind of responsiveness that traditional manual storage management processes cannot deliver. Still, it can also be customized so that all stakeholders get more accurate data aligned to their responsibility.
- SAN configuration management must be streamlined. With more enterprise applications demanding access to more data and virtual machines, deploying and configuring servers, storage, and the network has become more time-consuming and complex than ever. By streamlining SAN operations through automation, application provisioning workflows are simplified across hypervisor, network, and storage, delivering agility and responsiveness to meet dynamic business demands.
- IT service delivery is not always as responsive as the business demands. As organizations become increasingly reliant on world-class IT services for proactive, agile business decision-making, they must identify and eliminate bottlenecks to IT service delivery. These enhanced IT services must be delivered without hiring more storage administrators or boosting SAN-related CapEx spending. SAN automation is the only viable option to drive increased agility and closely align IT services with fast-changing business needs.
- Consistent configuration validation is a must. Manual configuration changes occur with greater frequency as enterprises diversify their IT architectures in general and their storage architectures specifically. SAN automation ensures the validation of consistent configuration parameters across the different SAN fabrics to facilitate troubleshooting of frequent alerts without reliance on manual intervention.

Broadcom automation solutions leverage RESTful APIs to facilitate solutions architecture, share best practices, and get to production faster.

16.3 Overview of the REST API

The FOS REST API is a programmable web service interface for Brocade Fabric OS that can manage Brocade SAN switches across a fabric. This API uses standard HTTP methods to perform Create, Read, Update, and Delete (CRUD) operations on the fabric configuration data. It provides an interface for provisioning, status, and validation operations using the YANG data model described in the YANG 1.1 RFC, but not the data store managed with NETCONF. An Apache webserver embedded in Fabric OS is used to serve the API.

The RESTful API approach lets you think of a network device as a webserver. Automation can send and receive transactions to or from a network device by using standard web-based tools just as it would send transactions to and from a website. Transactions of this nature mean that they happen over a secure socket using HTTP rules to handle the exchange. The data appears in XML or JSON depending on the RESTful API services implemented on the networking device.

To interact with a SAN (or other) device, you need to consult its RESTful API reference to learn, among other things, what uniform resource identifiers (URIs) you need to use. (Simply put, URIs are identifiers that can be used as part of a web address.) According to the documentation, the URI for accessing a list of zones in the active configuration is as follows:

```
GET <base_URI>/running/zoning/defined-configuration/
```

The model used to represent state and configuration information is expressed in a modeling language called Yang. Yang describes the structure of the different elements inside the model and describes whether each element is read-only or read-write. It describes the type of data that the element can hold, such as string or integer. It shows the relationship among various elements, the other nested elements they contain, their peer elements, and the parent elements that contain them. Here is a segment of the description of a zone in Yang:

```
list zone {
key "zone-name"; description
"List of the members in the zone. The members can be identified only as a WWN, domain, index, or zone
alias.";
leaf zone-name {
type zoning-name-type; description
"The zone name.";
}
leaf zone-type {
type zone-type-type; description
"The zone type. Not that target zone types cannot be created or modified (only deleted).";
}
container member-entry { description
"The zone member."; leaf-list entry-name {
type zone-member-type; min-elements 1; description
"List of the members in the zone. The members can be identified only as a WWN, domain, index, or zone
alias.";
}

leaf-list principal-entry-name {
when "../..zone-type=1 or ../../zone-type=2"; type zone-member-type;
min-elements 1; description
"List of the principal members in the peer zone. The members can be identified only as a WWN, domain,
index, or zone alias.";
}
}
}
```

Ordinarily, more information goes into a Yang module, such as revisioning and governance information; this listing omits them for brevity. Thus, the Yang description is complete, but it is also wordy. Although this precision is necessary when interacting with the model programmatically, it is sometimes helpful to get a global view of the abstraction provided by the model to see how the data is structured.

An open-source tool called pyang can parse the Yang model and produce a tree representing the model's elements. The listing includes information about each element, whether it is read-only or read-write, a list, optional, or nested. Here is the representation of the zoning model in tree form:

```
module: brocade-zone
+--rw brocade-zone
+--rw defined-configuration
|   +--rw cfg* [cfg-name]
|   |   +--rw cfg-namezoning-name-type
|   |   +--rw member-zone
|   |   +--rw zone-name*zoning-name-type
|   +--rw zone* [zone-name]
|   |   +--rw zone-namezoning-name-type
|   |   +--rw zone-type?zone-type-type
|   |   +--rw member-entry
|   |   +--rw entry-name*zone-member-type
|   |   +--rw principal-entry-name*zone-member-type
|   +--rw alias* [alias-name]
|   +--rw alias-namezoning-name-type
|   +--rw member-entry
|   +--rw alias-entry-name*union
+--rw effective-configuration
+--rw cfg-name?zoning-name-type
+--rw checksum?string
+--rw cfg-action?uint8
+--rw default-zone-access?uint8
+--ro db-max?uint32
+--ro db-avail?uint32

+--ro db-committed?uint32
+--ro db-transaction?uint32
+--ro transaction-token?uint32
+--ro db-chassis-wide-committed?uint32
+--ro enabled-zone* [zone-name]
+--ro zone-namezoning-name-type
+--ro zone-type?zone-type-type
+--ro member-entry
+--ro entry-name*union
+--ro principal-entry-name*union
```

16.4 Simple Automation Example

In this example, the <base_URI> is http://<our device IP address>/rest. Begin by creating a login session with a switch in the fabric by executing the following command (which you type as a single line):

```
curl -X POST -v -u admin:password http://10.18.254.37/rest/login
```

- `curl` is the command's name.
- `-X POST` specifies the POST HTTP method (instead of GET).
- `-v` specifies verbose output to access the authorization string in the header of the response used in the next step.
- `-u admin:password` specifies the credentials to use.

The last parameter is the uniform resource identifier (URI) for `curl` to use to log in. (The URI value is described in the RESTful API reference.)

This command establishes the session used for the following commands. The following is a trace of its execution:

```
*  Trying 10.18.254.37...
*  Connected to 10.18.254.37 (10.18.254.37) port 80
(#0)
*  Server auth using Basic with user 'admin'
POST /rest/login HTTP/1.1
>  Host: 10.18.254.37
Authorization: Basic YWRtaW46cGFzc3dvcmQ=
User-Agent: curl/7.47.0
Accept: */* >
<  HTTP/1.1 200 OK
<  Date: Wed, 31 Jan 2018 16:01:24 GMT
<  Server: Apache
<  Authorization: Custom_Basic YWRtaW46eHh4OjNkYTllZmM3NzMxYjk4OGU2ODg1YzZkMGRjNWJlM
zMyNjBhZDYxZThkOWQ2MWMxNzNiMGVlMjU3YmM2OTcyYjA=
< Cache-Control: no-cache
< X-Frame-Options: DENY
< Content-Secure-Policy: default-src 'self'
< X-Content-Type-Options: nosniff
< X-XSS-Protection: 1; mode=block
< Connection: close
< Transfer-Encoding: chunked
< Content-Type: application/yang-data+xml
```

Next, you perform a GET of the URI to return the current configuration using the Custom Basic value returned from the login for authentication:

```
curl -v -H "Authorization: Custom_Basic
YWRtaW46eHh4OjNkYTllZmM3NzMxYjk4OGU2ODg1YzZkMGRjNWJlM
zMyNjBhZDYxZThkOWQ2MWMxNzNiMGVlMjU3YmM2OTcyYjA="
http://10.18.254.37/rest/running/zoning/defined-configuration
```

By default, `curl` uses the GET method, so you do not need to specify it. `-H "Authorization: Custom_Basic YWR...jA="` is the authentication and session identifying string returned in the previous command. `-H` places the string into the GET request header as seen in the following trace:

```
*  Trying 10.18.254.37...
*  Connected to 10.18.254.37 (10.18.254.37) port 80
(#0)
   GET /rest/running/zoning/defined-configuration HTTP/1.1
   Host: 10.18.254.37
   User-Agent: curl/7.47.0
   Accept: */*
   Authorization: Custom_Basic YWRtaW46eHh4OjNkYTllZmM3NzMxYjk4OGU2ODg1YzZkMGRjNWJlM
zMyNjBhZDYxZThkOWQ2MWMxNzNiMGVlMjU3YmM2OTcyYjA=
>
<  HTTP/1.1 200 OK
<  Date: Wed, 31 Jan 2018 16:09:39 GMT
<  Server: Apache
<  Cache-Control: no-cache
<  X-Frame-Options: DENY
<  Content-Secure-Policy: default-src 'self'
<  X-Content-Type-Options: nosniff
<  X-XSS-Protection: 1; mode=block
<  Connection: close
<  Transfer-Encoding: chunked
<  Content-Type: application/yang-data+xml <
<?xml version="1.0"?>
<Response>
<defined-configuration>
<cfg>
<cfg-name>CFG_FABRIC_A</cfg-name> <member-zone> <zone-name>CLUSTER1</zone-name>
<zone-name>Z_AIXHOST_FCS2_VMAX01_SN1234_9F0 </zone-name>
...
<alias> <alias-name>esx66_5d3d00</alias-name> <member-entry> <alias-entry-
name>10:00:8c:7c:ff:5d:3d:00 </alias-entry-name>
</member-entry>
</alias>
</defined-configuration>
</Response>
* Closing connection 0
```

The results appear as an XML data segment structured according to the Yang model's description, so it is crucial to have access to that model along with the RESTful API manual. The models can be found on GitHub as a repository among Broadcom's repositories at http://github.com/brocade/yang. The RESTful API manual can be retrieved from the Broadcom website. Having retrieved the zoning information from the fabric, you should close the session using the CLI command (the results are omitted to save space):

```
curl -v -H "Authorization: Custom_Basic
YWRtaW46eHh4OjNkYTllZmM3NzMxYjk4OGU2ODg1YzZkMGRjNWJlM
zMyNjBhZDYxZThkOWQ2MWMxNzNiMGVlMjU3YmM2OTcyYjA=" http://10.18.254.37/rest/logout
```

In FOS version 8.2.2 or later, the REST API session-less operation allows you to provide authentication credentials directly for each GET request. Essentially, the FOS REST API session-less operation completes the login, GET operation, and logout as one complete request. You can use only basic authentication formats for REST API session-less operation, including plain text or Base64.

The following example shows a GET request using plain-text authentication:

```
curl -u admin:password http://10.155.2.190/rest/running/brocade-media/media-rdp>"
```

16.5 Ansible as an Alternative

The previous section shows an example of an approach that uses a procedural methodology. The workflow starts at the beginning, executes a series of steps, and then terminates. Most traditional programs work this way.

Ansible takes a declarative approach. Rather than provide sequential steps, Ansible describes each host in an inventory. The description appears in a document called a playbook. For example, Ansible describes a host state where the application is already installed rather than providing steps to install a particular application. When you run the playbook, Ansible takes no action if the application is already installed. If the application is not installed, Ansible calls installation routines to bring the host into the desired state without requiring the administrator to write specific steps.

In the realm of storage networks, using declarative language means that you can describe switches and fabrics where, for example, a zone is already configured with the proper hosts and storage arrays. When you run the Ansible playbook, those zones are defined as needed, and the hosts and storage arrays are added if necessary.

With some other declarative automation utilities, installing an agent on each managed host is necessary. This agent retrieves the commands from a command center and runs them on the localhost. Ansible is unique in that it does not require agents. Ansible establishes a secure shell session to a proxy and sends it a small Python script to make switch state changes. The script performs the necessary operations using the switch API and removes itself from the host.

You need two different skill sets to implement an Ansible solution successfully. First, you must understand the most common playbook operations. These operations are coded and installed for use by the playbooks. As vendors announce support for Ansible, they also provide script libraries for the most common tasks. Suppose there is a required task, but it is not available in the official Ansible distribution. In that case, the open-source community might provide code for that task in publicly available repositories.

Second, you must understand your business needs to provide ongoing playbook development. The person who maintains the playbooks does not need to be a programmer and does not need to know how remote system operations occur. That person needs to know only the desired outcomes and should be able to construct playbooks in YAML, the markup language used by Ansible. The following is an example of an Ansible playbook:

```
---
- hosts: edgeSwitches vars_files:
-../fos_passwords.yml gather_facts: False

tasks:

- name: run fos commands brocade_fos_command:
switch_login: "{{switch_admin_account}}" switch_password: "{{switch_password}}" switch_address:
"{{switch_ip_address}}" command_set:
- command: alicreate "SampleAlias1", "10:23:45:67:76:54:32:10"
```

The three dashes at the beginning are part of the YAML specification. The `hosts` section identifies automation target switches. You can keep sensitive information in a separate file, as demonstrated by the `fos_passwords.yml` line. The name of a variable in double braces such as `{{switch_password}}` indicates variable substitution. The variable file specified in `vars_files` tells where to find external variables.

16.6 SANnav REST API

SANnav Management Portal and SANnav Global View provide end-to-end visibility into enterprise SANs. These tools detect, analyze, and take action based on SAN behavior and performance, helping administrators get to the root of problems faster and remediate them fully. Storage administrators can troubleshoot across the storage fabric in as little as 30 seconds. These capabilities are unprecedented with any other shared storage infrastructure architecture.

The SANnav Management Portal REST APIs provide functionality that complements the Fabric OS REST APIs. The SANnav REST API feature details can be found in the *Brocade SANnav Management Portal REST API and Northbound Streaming Reference Manual* located here. Currently there are no REST interfaces provided by SANnav Global View.

16.7 Conclusion

SAN automation is a critical element in IT modernization and digital transformation. It helps organizations handle storage-related processes more efficiently without hiring more administrators or adding to the storage infrastructure CapEx budget. SAN automation is a high-leverage approach to turning network storage into a strategic asset.

Broadcom's commitment to SAN automation and long-standing leadership in storage fabrics and technical innovation make it an ideal candidate for your IT infrastructure automation strategy.

Appendix A: Optical Cables

Table 3: Supported Distances Based on Cable Type and Data Rates

Speed Name	OM1 Link Distance 62.5-µm Core and 200 MHz*km	OM2 Link Distance 50-µm Core and 500 MHz*km	OM3 Link Distance 50-µm Core and 2000 MHz*km	OM4 Link Distance 50-µm Core and 4700 MHz*km	OS1 Link Distance 9-µm Core and ~Infinite MHz*km
1GFC	300	500	860	*	10,000
2GFC	150	300	500	*	10,000
4GFC	50	150	380	400	10,000
8GFC	21	50	150	190	10,000
10GFC	33	82	300	*	10,000
16GFC	15	35	100	125	10,000
32GFC	—	20	70	100	10,000

Table 4: LWL Optics Support (SFP+)

Transceiver Data Rate (Gb/s)	Distance (km)
4	4, 10, and 30
8	10, 25
10	10
16	10
32	10

Appendix B: Fabric Details

This appendix provides example checklists and tables that you can use to identify dominant factors, including facilities that will have an impact on the SAN design.

Table 5: Current Fabrics

SAN/Fabric	No. of Switches	Type of Switches	Total Ports	Domains	No. of Servers	No. of Storage Devices	Location	Notes
Fabric 1								
Fabric 2								
Fabric 3								
Fabric 4								
Fabric 5								

Table 6: Individual Fabric Details

SAN/Fabric	Domain Number	Serial Number	Model	Speed	WWN	IP Addresses	Brocade FOS/M-EOS Version	Notes
Switch 1								
Switch 2								
Switch 3								
Switch 4								
Switch 5								

Table 7: Device Details

Servers and Storage	Vendor	Model	WWN	Alias	Zone	OS Version	Application	Fabric/ Switches	Notes
Server 1									
Server 2									
Server 3									
Storage 1									
Storage 2									
Storage 3									

Table 8: Metrics and Impact on SAN Design and Performance

Metric	Source	Impact
Servers in the SAN	Estimate/Brocade SAN Health	Normal operations
Host Level Mirroring	Estimate	Distance, ISL congestion, traffic levels
Clusters (MSFT, HACMP, NetApp) Average number of nodes Workload level	Estimate Estimate: High/Med/Low	In-band heartbeat, frame congestion, host fan-in, traffic isolation
Virtualization: VIO Server No. of servers Consolidation ratio	Estimate Estimate Estimate	Frame congestion, edge traffic increase per port, server fan-in on target ports, device latencies
Virtualization: VMware No. of VMware servers Consolidated ratio? Shared VMFS? DRS? RDM? I/O intensive?	Estimate Estimate Yes/No Yes (%)/No Yes (%)/No High/Med/Low Yes/No	Frame congestion, device latencies, and SCSI2 reservations

Table 9: Consolidated SAN Snapshot

SAN Requirements Data (Complete for Each SAN)	
Fabric Information	
Target number of user ports per fabric	
Target number of total ports per fabric	
Target number of switches per fabric (number of switches/switch type, total switches)	
Number of fabrics	
Number of sites in environment	
Topology (core-edge, ring, mesh, other)	
Maximum hop count	
Expected growth rate (port count)	
Fabric licenses	
SAN Device Information	
Number/types of hosts and OS platforms	
Number/types of storage devices	
Number/types of tapes	
Number/types of HBAs	
Other devices (VTL/deduplication appliance)	
Total number of SAN devices per fabric	
Customer requirement for failover/redundancy, reliability of SAN (multipathing software utilized)	

Table 9: Consolidated SAN Snapshot (Continued)

SAN Requirements Data (Complete for Each SAN)	
Application Details	
SAN Application (Storage Consolidation, Backup and Restore, Business Continuance)	
Fabric management application(s)	
Performance	
Maximum latency (ms)	
Targeted ISL oversubscription ratio (3:1, 7:1, 15:1, other)	

Table 10: Application-Specific Details

Backup/Restore Infrastructure		
Servers		
System	OS Version, Patch Level	HBA Driver Version
Server 1/HBA		
Server 2/HBA		
Server 3/HBA		
Backup Software		
Vendor	Version	Patch
FC Switch		
Vendor	Model	Firmware
Brocade		
Storage		
Vendor	Model	Firmware
Array 1		
Array 2		
Tape Library		
Vendor	Model	Firmware
Library		

NOTE: Keep a similar table for each application.

Table 11: Quantitative Analysis: Radar Maps

SAN/Storage Admin Concerns	Rank (1 is Low, 10 is High)	Notes
ISL utilization	8	Is traffic balanced across ISLs during peaks?
Switch outage	1	Have there been switch outages? If so, what was the cause?
Zoning policy	6	Is the zoning policy defined?
Number of switches in the fabric	10	Is the current number of switches a concern for manageability?
Scalability	6	Can the existing design scale to support additional switches, servers, and storage?
Redundancy	10	Is the existing SAN redundant for supporting a phased migration or firmware update?
Server: high availability	10	Does the cluster software fail over reliably?
Storage: high availability	10	Do the LUNs fail over reliably?
Available disk pool	6	Is there a sufficient disk pool to support additional apps?
Management tools for SAN	4	Are the right tools used for SAN management?
Application response	7	Have there been any instances of slow application response but no outage?

Appendix C: Terminology

Term	Brief Description
ACC	Automated Case Creation is part of the Brocade Support Link (BSL) suite.
ACL	Access control list is a list of permissions associated with a system resource (object).
AFA	All FLASH Array.
AG	Access Gateway is an FC switching product from Broadcom.
air gap	Air gap is the separation that creates true redundancy between the A and B fabrics in a SAN. Other than the hosts, storage, and management connections, there are no other connections between the A and B fabrics.
ARL	Adaptive Rate Limiting is a two-tier rate limiter. A minimum value and maximum value are configured. Always push at least the min; never push more than the max.
ASC-G	Active Support Connectivity Gateway is used with Brocade Support Link.
ASIC	Application-specific integrated circuit made by Broadcom for Brocade FC switching products.
Base Switch	Base switch of an enabled virtual fabric mode switch, providing a common communication infrastructure that aggregates traffic from logical switches in the physical switch in a common base fabric.
BBC	Buffer to Buffer Credit is part of the FC flow control mechanism.
BBFID	Backbone Fabric ID is an ID number identifying a specific backbone fabric used in FCR.
BET	Brocade Extension Trunking is a trunking feature specific to an Extension tunnel when it is comprised of more than one circuit.
BPA	Best Practice Assessment, part of Brocade Support Link.
BSL	Brocade Support Link.
BT	Brocade Trunk allows a group of ISLs to merge into a single logical link, enabling traffic to be distributed dynamically at the frame level. BT egress queueing reduces I/O response time.
BW	Bandwidth, as in link bandwidth or WAN bandwidth.
CA	Certificate Authority is an authorized entity that signs identity certificates.
certificate	A certificate provides authentication of the identity claimed. Within the National Security System (NSS) public key infrastructure (PKI), identity certificates might be used for authentication or for both authentication and digital signatures.
ClearLink Diagnostics	Diagnostics tool that allows users to automate a battery of tests to verify the integrity of optical cables and transceivers in the fabric.
CPI	Configuration, Performance, and Inventory (CPI) reports provide a comprehensive package of all configuration, inventory, and performance data.
CPU	A central processing unit (CPU), also called a central processor, main processor, or just processor, is the electronic circuitry that executes instructions comprising a computer program.
CRC	A cyclic redundancy check (CRC) is an error-detecting code commonly used in digital networks and storage devices to detect accidental changes to digital data.

Term	Brief Description
CRUD	Create, Read, Update, Delete.
DBR	Device-Based Routing routes flows based on SID/DID.
DCA	Data Collection Assistant is enabled with ASC-G as a centralized point for SupportSave triggering or end-user scheduling.
DCC	Device Connection Control is a FOS-based security feature.
DH-CHAP	Diffie-Hellman Challenge Handshake Authentication Protocol is an FC-SP protocol that provides authentication between switches and connected devices.
DID	Domain ID is the domain assigned to the switch or logical switch. It must be unique within the fabric.
DNS	Domain Name Service is a network service used to resolve human readable fully qualified domain names into an IP address or some other information.
D_Port	A Fabric Port configured in ClearLink Diagnostics testing mode for cable and optics integrity testing.
DP	Data processor is used for Extension to put data into circuits and tunnels, perform encryption and compression, and perform all other Extension functions.
DR	Disaster recovery is an organization’s plan to mitigate and recover from catastrophes to their infrastructure and staff.
DS	A default switch is a logical switch in a virtual fabric mode switch and is automatically created when Virtual Fabrics is enabled.
EBR	Exchange-Based Routing routes flows based on OxID/SID/DID
EFID	Edge Fabric ID is the ID number assigned to an edge fabric.
ELWL	Extended Long Wavelength is an SFP type that has very long distance capabilities.
E_Port	A standard Fibre Channel mechanism that enables switches to network with each other.
Extension	Extension is a technology used to transport FC (FCIP) or IP (IPEX) over an IP network in an optimized manner.
EX_Port	A type of E_Port that is a Fibre Channel router port and the demarcation point of fabric services. EX_Ports connect to edge fabrics.
FC	Fibre Channel.
FCAP	FC Authentication Protocol.
FCIP	Fibre Channel over IP enables Fibre Channel traffic to flow over an IP WAN.
FCP	FC Protocol.
FCR	FC Routing enables multiple fabrics to share devices without merging the fabrics.
FCS	Fabric Configuration Server is a Brocade FOS feature.
FDMI	Fabric Device Management Interface enables discovery of devices such as FC host bus adapters (HBAs).
FEC	Forward Error Correction is a technique used for controlling errors in data transmission over ultra-high-speed connections, unreliable transmission media, and noise-susceptible environments.
FICON	Fiber Connect is the IBM proprietary name for the ANSI FC-SB-3 Single-Byte Command Code Sets-3 Mapping Protocol for the FC protocol.
FID	Fabric ID is a unique identification number within the fabric.
FMS	FICON Management Server is a Brocade FOS feature.
FOS	Fabric Operating System, which runs on Brocade switches and directors.
FPI	Fabric Performance Impact is a Brocade FOS feature involving thresholds in MAPS.
FPIN	Fabric Performance Impact Notification.
F_Port	Fabric Port is a port in the fabric to which an N_Port is attached.

Term	Brief Description
GE	Gigabit Ethernet.
HBA	Host bus adapter.
HDD	Hard disk drive.
HSRP	Hot Standby Router Protocol.
HTTP/HTTPS and SFTP	Hypertext Transfer Protocol and Hypertext Transfer Protocol Secure (HTTPS) are a combination of HTTP with the Secure Socket Layer (SSL)/Transport Layer Security (TLS) protocol. Secure FTP uses the same SSL/TLS protocol to secure FTP.
ICL	Inter-chassis links are connections between directors using the ICL ports.
IFL	Inter-fabric links are connections between a backbone fabric and edge fabricsing EX_Ports.
IO	Storage-based data Input (write) and Output (read).
IOPS	I/Os per second, the rate of I/Os.
ISL	Inter-switch links are used for connecting switches and directors using E_Ports.
LF	Logical fabric, the fabric comprised of multiple logical switches in a virtual fabric.
IP	Internet Protocol (IPv4 or IPv6).
IP Extension (IPEX)	The encryption and optimization of IP storage transport using Extension.
IPEX GW	IP Extension Gateway is an interface on the LAN side of Extension to which IP storage sends its traffic.
KATOV	Keepalive Timeout Value used by Extension circuits to determine how long before going offline.
LAN	Local area network, typically within the data center.
LDAP	Lightweight Directory Access Protocol is an open, vendor-neutral, industry-standard application protocol for accessing and maintaining distributed directory information services over an IP network.
LLDP	Link Layer Discovery Protocol (LLDP) is a vendor-neutral link layer protocol used by network devices for advertising their identity, capabilities, and neighbors on a local area network based on IEEE 802 technology, principally wired Ethernet.
LS	Logical switch, part of a virtual fabric enabled switch, managed the same as physical switches.
LSAN	Logical SAN refers to the type of zoning used for FCR between devices in different edge fabrics.
LUN	A logical unit number is a number used to identify a logical unit, which is a device addressed by the SCSI protocol or SAN protocols that encapsulate SCSI, such as Fibre Channel or iSCSI.
LWL	Long Wavelength is an SFP capable of long distances, usually over single-mode fiber.
MAN	A metropolitan area network (MAN) is a computer network that interconnects users with computer resources in a geographic region of the size of a metropolitan area.
MAPS	Monitoring Alerting Policy Suite is a FOS feature that constantly monitors itself for potential faults and automatically alerts the user to detected problems.
MMF	Multi-mode optical fiber is a type of optical fiber mostly used for communication over short distances, such as within a building or on a campus. Multi-mode links can be used for data rates up to 100 Gb/s.
MPIO	Multipath I/O is a fault-tolerance and performance-enhancement technique that defines more than one physical path between a computer system and its storage.
NAS	Network attached storage.
NIC	Network interface card.
NPIV	N_Port ID Virtualization is an FC feature whereby multiple FC Node Port (N_Port) IDs can share a single physical N_Port.
N_Port	Node Port is a port on the end device (host or storage).
NSID	NVMe Namespace ID.

Term	Brief Description
NVMe	NVM Express (NVMe) or Non-Volatile Memory Host Controller Interface Specification (NVMHCIS) is an open, logical-device interface specification for accessing a computer's non-volatile storage media usually attached through a PCI Express (PCIe) bus.
OVA/OVF	An OVF package consists of several files placed in one directory. The entire directory can be distributed as an Open Virtual Appliance (OVA) package, which is a tar archive file with the OVF directory inside.
Oversubscription	A condition in which more devices might need to access a resource than that resource can fully support.
PBR	Port-Based Routing is routing based on the port numbers.
PG	A performance group is a set of virtual channels dedicated to traffic based on certain criteria.
port channel	A port channel allows grouping of several physical Ethernet links to create one logical Ethernet link for the purpose of providing fault-tolerance and more bandwidth to switches.
port group	A set of ports that have in common a particular function or feature, such as BT.
QoS	Quality of Service is a traffic queueing mechanism that prioritizes data based on the initiator and target zoning designation (high, medium, or low). QoS also applies to Extension traffic.
QSFP	Quad small form-factor pluggable is a four-lane SFP and can accommodate four times the speed.
RADIUS	Remote Authentication Dial-In User Service (RADIUS) is a networking protocol that provides centralized authentication, authorization, and accounting (AAA) management for users who connect and use a network service.
RAID	Redundant Array of Inexpensive Disks or Redundant Array of Independent Disks is a data storage virtualization technology that combines multiple physical disk drive components into one or more logical units for the purposes of data redundancy and performance improvement.
RASLog	Reliability Availability Serviceability Log is the logging facility on Brocade FOS-based platforms.
RBAC	Role-based access control (RBAC) or role-based security is an approach to restricting access to authorized users and authorizing specific functions based on their defined role.
RDR	Remote Data Replication is asynchronous replication that occurs between one data center and another over distance.
redundancy	Duplication of components, including an entire fabric, to avoid a single point of failure in the network (fabrics A and B are identical).
resiliency	The ability of a fabric to recover from failure; could be in a degraded state but functional (for example, an ISL failure in a trunk group).
REST and RESTful	Representational state transfer (REST) is a widely accepted set of guidelines for creating stateless, reliable web-based APIs. RESTful web APIs are typically based on HTTPS methods to access resources through URL-encoded parameters and the use of JSON or XML to transmit data.
RSCN	Registered state change notification (RSCN) is an FC fabric's notification sent to specific nodes in case of fabric changes.
RTT	Round trip time.
SAN	Storage area network, typically comprised of two or more fabrics.
SCC	Switch Connection Control is a Brocade FOS security feature.
SCSI	Small Computer System Interface is a set of standards for physically connecting and transferring data between computers, storage, and peripheral devices.
SDDQ	Slow Drain Device Quarantine is a Brocade FOS feature used to remove slow devices from the fast lanes and place them into their own slower traffic lane. SDDQ mitigates or eliminates head of line blocking.
SFP and SFP+	Small form-factor pluggable is a compact, hot-pluggable, network interface module used for both telecommunication and data communications applications.
SLA	A service-level agreement is an organizational agreement to maintain a specific level of infrastructure operational availability.

Term	Brief Description
SMF	Single-mode fiber is an optical fiber designed to carry only a single mode of light. SMF fiber is associated with LWL and can carry light farther distances than MMF.
SNMP	Simple Network Management Protocol is an Internet standard protocol for collecting and organizing information about managed devices on IP networks and for modifying that information to change device behavior.
SSD	Solid state disk.
SSH	Secure Shell is a client-to-host protocol used to form a secure encrypted connection to the CLI.
SSL	Transport Layer Security (TLS) is the successor of the now-deprecated Secure Sockets Layer (SSL). SSL is a cryptographic protocol designed to provide communications security over a computer network.
SWL	Short Wavelength is associated with MMF (multi-mode fiber) and tends to carry light for short distances.
TCL	Traffic control list is part of the configuration of IP Extension. Matching traffic is assigned to a particular tunnel.
TCO	Total cost of ownership is the cost when accounting for all aspects of the business including acquisition, learning, staffing, operations, downtime, installation, maintenance, future replacement, product lifecycle, and so on.
TCP	Transmission Control Protocol (TCP) is one of the main protocols of the Internet protocol suite.
TIZ	A traffic isolation zone controls inter-switch traffic by creating a deterministic path for traffic flowing between a specific set of source ports. NOTE: The TIZ feature has been deprecated.
TLS	The Transport Layer Security protocol aims primarily to provide cryptography, including privacy (confidentiality), integrity, and authenticity through the use of certificates, between two or more communicating computer applications.
TLV	Type, length, value is an encoding scheme used for optional informational elements in certain protocols.
TO	Traffic Optimizer is a Brocade FOS feature used to sort traffic by characteristic into the most optimal traffic lanes to expedite delivery through the fabric.
UDP	User Datagram Protocol (UDP) is one of the core members of the Internet protocol suite. Applications send messages referred to as datagrams to other hosts on an IP network.
UI	A user interface can be a browser or some other interactive form with the application.
URI	Uniform Resource Identifier (URI) is a unique sequence of characters that identifies a logical or physical resource used by web technologies.
VC	Virtual channels create multiple logical data paths (queues) across a single physical link.
VE_Port	Virtual Expansion Port is specific to Extension. It is a type of E_Port that faces the WAN and connects to the IP network. VE_Ports connect to VE_Ports in remote data centers.
VF	Virtual Fabrics is a suite of related features that enable customers to create logical switches and logical fabrics.
VLAN	Virtual LAN is a logically separated LAN within the physical LAN devices. VLANs are assigned and identified by number.
VM	Virtual machine is a virtual server instance created on a physical server that might have multiple VMs running on it. Each VM can be constructed with its own set of characteristics.
VRRP	Virtual Router Redundancy Protocol (VRRP) is a networking protocol that provides for a Virtual IP (VIP) and Virtual MAC (VMAC) for a set of router gateways on a LAN. The VIP and VMAC can provide failover/failback from one GW to another.
WAN	Wide area network is a network that typically reaches beyond the metropolitan area and is IP based.
WWN	World Wide Name is a unique identifier used in storage technologies. There are WWNs for ports (pWWN or WWPN) and nodes (nWWN or WWNN). There might be other WWNs on a device as well.

Term	Brief Description
UltraScale ICL	UltraScale inter-chassis link, used for connecting director chassis (Gen 6 and Gen 7) without using front-end device ports.
xISL	xISL is an ISL that uses tagging to connect two virtual fabric base switches. All logical switches in each chassis that have enabled the use of xISL can communicate across the physical xISL links forming logical fabrics.

Appendix D: References

D.1 Compatibility, Scalability, and Target Path

Broadcom.com

- Brocade Fabric OS 9.x Open Systems Compatibility Matrix

Broadcom Customer Support Portal (CSP)

- Brocade SAN Scalability Guidelines: Brocade Fabric OS v9.x
- Brocade Fabric OS Target Path Selection Guide

D.2 Brocade SAN Health

www.broadcom.com/sanhealth

D.3 Brocade Bookshelf

- NVMe over Fibre Channel for Dummies
- Networking Next-Gen Storage for Dummies
- Brocade Mainframe Connectivity Solutions
- SAN Automation for Dummies

D.4 Other

- The SNIA Dictionary
- SAN System Design and Deployment Guide

Revision History

53-1004781-06; May 10, 2024

- Updated long-distance measurements in Predeployment Cabling and Optics Validation.

53-1004781-05; August 15, 2023

- Adjusted cover page content.

53-1004781-04; July 2023

- Added updated for Brocade 7850.
- Reviewed, updated, and edited the design guide in its entirety.

53-1004781-03; January 2023

- Added updates for FOS 9.2.
- Removed Extension (Extension now has its own similar document).
- Reviewed, updated, and edited the design guide in its entirety.

53-1004781-03; May 2022

- Added updates for FOS 9.1.
- Reviewed, updated, and edited the design guide in its entirety.

53-1004781-02; September 1, 2020

- Added updates for FOS 9.0 and Gen 7.
- Added the “Automation” chapter.

53-1004781-01; November 23, 2016

Initial release.

BROCADE®
A Broadcom Company