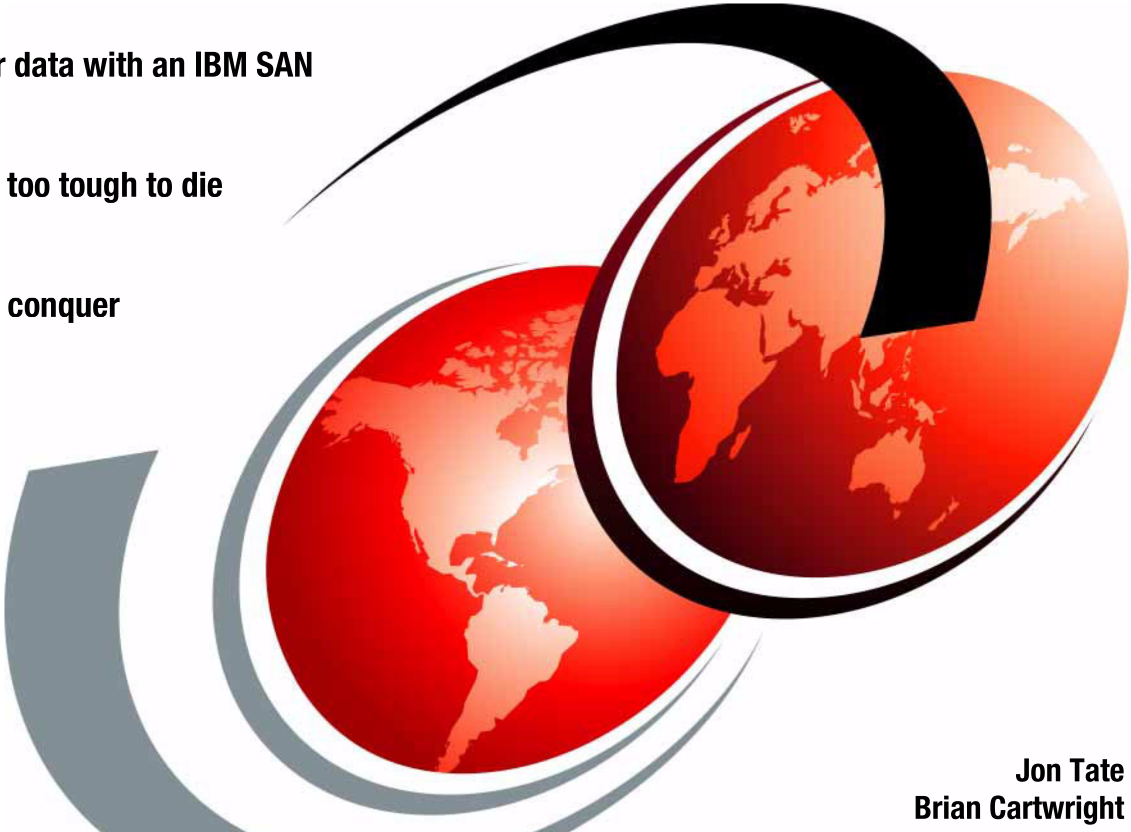
IBM SAN Survival Guide Featuring the IBM 3534 and 2109

Protect your data with an IBM SAN

Build a SAN too tough to die

Survive and conquer



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International Technical Support Organization

IBM SAN Survival Guide Featuring the IBM 3534 and 2109

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Note: Before using this information and the product it supports, read the information in "Notices" on page xvii.

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This edition applies to those products in the IBM TotalStorage portfolio.

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Preface

As we all know, large ocean going ships never collide with icebergs. If this is the case, there would not seem to be much of a market opening for this IBM® Redbook. However, occasionally life deals out some unexpected pleasures for us to cope with. Surviving any disaster in life is usually a lot easier if you have prepared adequately by taking into account the likely problems, solutions, and their implementation. This can be summarized by the rule of the six P's:

Proper Preparation Prevents Pretty Poor Performance

In this IBM Redbook, we limit ourselves to those situations in which it is likely that a SAN will be deployed. We discuss considerations that need to be taken into account to ensure that no SAN designer is hoisted by their own petard. We present the IBM SAN portfolio of products, going a little under the surface to show the fault tolerant features that they utilize, and then describe solutions we have designed with all these features taken into account.

The various models of the IBM TotalStorage™ SAN Fibre Channel Switch 2109 and 3534-F08 provide Fibre Channel connectivity to a large variety of Fibre Channel attached servers and disk storage, including the IBM TotalStorage Enterprise Storage Server™™ (ESS), FAStT Storage Servers, SAN Data Gateways for attachment of IBM Enterprise Tape systems 358x, and tape subsystems with native Fibre Channel connections.

Each of the solutions that we show has been built on the blood, sweat, and tears of practical experience in the House of SAN. The designs themselves have been built, in some cases with cost in mind, in some cases with no cost in mind.

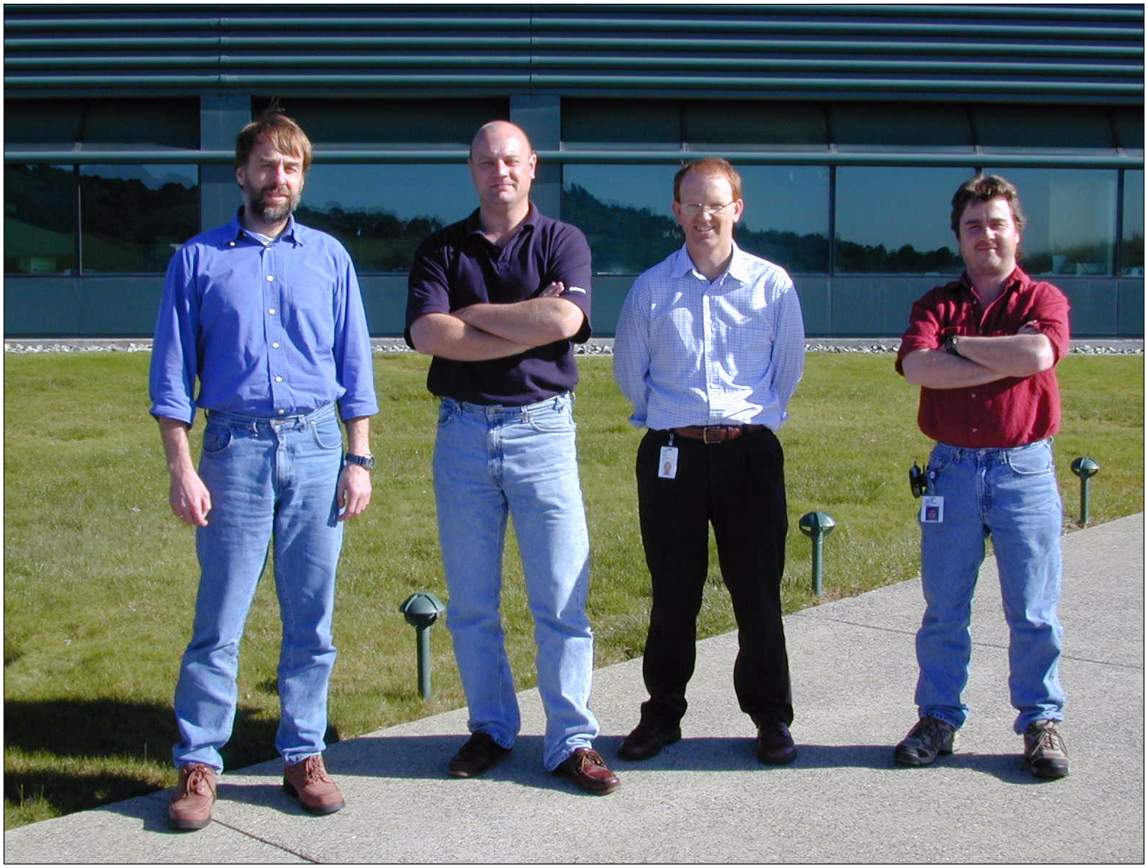
We understand that in this financially constrained world, life is not so easy as we describe it on paper. But that does not make the solutions any less valid. Any good, well-thought-out SAN design will have taken every single concern into account, and either formulated a solution for it, or ignored it, but nonetheless understanding the potential exposure.

IBM brings a vast amount of muscle to the SAN arena, and in this redbook, we have two objectives. First, we position the IBM SAN products that are currently in our portfolio. Second, we show how those products can be configured together to build a SAN that not only allows you to survive most forms of disaster, but also provides performance benefits.

So, make sure that you know what to do if you hit an iceberg!

The team that wrote this redbook

This redbook was produced by a team of specialists from Australia, Germany, the US, and the UK working at the International Technical Support Organization, San Jose Center.



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Part 1

Survival tactics

“It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.”

Sherlock Holmes.

As we have no wish to make a capital mistake, we will describe some of the components, features, and disciplines that are an essential piece of the survival jigsaw.

1

Introduction

Until recently, disaster planning for businesses focused on recovering centralized data centers following a catastrophe, either natural or man-made. While these measures remain important to disaster planning, the protection they provide is far from adequate for today's distributed computing environments.

The goal for companies today is to achieve a state of business continuity, where critical systems and networks are always available. To attain and sustain business continuity, companies must engineer availability, security, and reliability into every process from the outset.

In this chapter we consider the many benefits SAN has to offer in these areas.

1.1 Beyond disaster recovery

When disaster recovery emerged as a formal discipline and a commercial business in the 1980s, the focus was on protecting the data center — the heart of a company's heavily centralized IT structure. This model began to shift in the early 1990s to distributed computing and client/server technology.

At the same time, information technology became embedded in the fabric of virtually every aspect of a business. Computing was no longer something done in the background. Instead, critical business data could be found across the enterprise — on desktop PCs and departmental local area networks, as well as in the data center.

This evolution continues today. Key business initiatives such as enterprise resource planning (ERP), supply chain management, customer relationship management and e-business have all made continuous, ubiquitous access to information crucial to an organization. This means business can no longer function without information technology in the following areas:

- Data
- Software
- Hardware
- Networks
- Call centers
- Laptop computers

A company that sells products on the Web, for example, or supports customers with an around-the-clock call center, must be operational 24 hours a day, 7 days a week, or customers will go elsewhere. An enterprise that uses e-business to acquire and distribute parts and products is not only dependent on its own technology but that of its suppliers. As a result, protecting critical business processes, with all their complex interdependencies, has become as important as safeguarding data itself.

The goal for companies with no business tolerance for downtime is to achieve a state of business continuity, where critical systems and networks are continuously available, no matter what happens. This means thinking proactively: engineering availability, security, and reliability into business processes from the outset — not retrofitting a disaster recovery plan to accommodate ongoing business continuity requirements.

1.1.1 Whose responsibility is it?

Many senior executives and business managers consider business continuity the responsibility of the IT department. However, it is no longer sufficient or practical to vest the responsibility exclusively in one group. Web-based and distributed computing have made business processes too complex and decentralized. What's more, a company's reputation, customer base and, of course, revenue and profits are at stake. All executives, managers, and employees must therefore participate in the development, implementation, and ongoing support of continuity assessment and planning.

The same information technology driving new sources of competitive advantage has also created new expectations and vulnerabilities. On the Web, companies have the potential to deliver immediate satisfaction — or dissatisfaction — to millions of people. Within ERP and supply chain environments, organizations can reap the rewards of improved efficiencies, or feel the impact of a disruption anywhere within their integrated processes.

With serious business interruption now measured in minutes rather than hours, even success can bring about a business disaster. Web companies today worry more about their ability to handle unexpected peaks in customer traffic than about fires or floods — and for good reason. For example, an infrastructure that cannot accommodate a sudden 200 percent increase in Web site traffic generated by a successful advertising campaign can result in missed opportunities, reduced revenues, and a tarnished brand image. Because electronic transactions and communications take place so quickly, the amount of work and business lost in an hour far exceeds the toll of previous decades. According to reports, the financial impact of a major system outage can be enormous:

- US$6.5 million per hour in the case of a brokerage operation
- US$2.6 million per hour for a credit-card sales authorization system
- US$14,500 per hour in automated teller machine (ATM) fees if an ATM system is offline

Even what was once considered a minor problem — a faulty hard drive or a software glitch — can cause the same level of loss as a power outage or a flooded data center, if a critical business process is affected. For example, it has been calculated that the average financial loss per hour of disk array downtime stands at:

- US$29,301 in the securities industry
- US$26,761 for manufacturing
- US$17,093 for banking
- US$9,435 for transportation

More difficult to calculate are the intangible damages a company can suffer: lower morale and productivity, increased employee stress, delays in key project time lines, diverted resources, regulatory scrutiny, and a tainted public image. In this climate, executives responsible for company performance now find their personal reputations at risk. Routinely, companies that suffer online business disruptions for any reason make headlines the next day, with individuals singled out by the press. Moreover, corporate directors and officers can be liable for the consequences of business interruption or loss of business-critical information. Most large companies stipulate in their contracts that suppliers must deliver services or products under any circumstances. What's more, adequate protection of data may be required by law, particularly for a public company, financial institution, utility, health care organization, or government agency.

Together, these factors make business continuity the shared responsibility of an organization's entire senior management, from the CEO to line-of-business executives in charge of crucial business processes. Although IT remains central to the business continuity formula, IT management alone cannot determine which processes are critical to the business and how much the company should pay to protect those resources.

1.1.2 The Internet brings increased risks

A recent IBM survey of 226 business recovery corporate managers revealed that only eight percent of Internet businesses are prepared for a computer system disaster. Yet doing business online means exposing many business-critical applications to a host of new risks. While the Internet creates tremendous opportunity for competitive advantage, it can also give partners, suppliers, customers, employees and hackers increased access to corporate IT infrastructures. Unintentional or malicious acts can result in a major IT disruption. Moreover, operating a Web site generates organizational and system-related interdependencies that fall outside of a company's control from Internet Service Providers (ISP) and telecommunications carriers to the hundreds of millions of public network users.

Therefore, the greatest risk to a company's IT operations may no longer be a hurricane, a 100-year flood, a power outage, or even a burst pipe. Planning for continuity in an e-business environment must address vulnerability to network attacks, hacker intrusions, viruses, and spam, as well as ISP and telecommunication line failures.

1.1.3 Planning for business continuity

Few organizations have the need or the resources to assure business continuity equally for every functional area. Therefore, any company that has implemented a single business continuity strategy for the entire organization is likely under-prepared, or spending money unnecessarily. The key to business continuity lies in understanding your business, determining which processes are critical to staying in that business, and identifying all the elements crucial to those processes. Specialized skills and knowledge, physical facilities, training, and employee satisfaction, as well as information technology, should all be considered. By thoroughly analyzing these elements, you can accurately identify potential risks and make informed business decisions about accepting, mitigating or transferring those risks.

Once you have developed a program for assuring that critical processes will be available around the clock, you should assume that it will fail — and commit to keeping your program current with business and technology infrastructure changes. A fail-safe strategy assumes that no business continuity program can provide absolute protection from every type of damage — no matter how comprehensive your high-availability, redundancy, fault tolerance, clustering, and mirroring strategies.

Today, the disasters most likely to bring your business to a halt are the result of human error or malice: the employee who accidentally deletes a crucial block of data; the disgruntled ex-employee seeking revenge by introducing a debilitating virus; the thief who steals vital trade secrets from your mainframe; or the hacker who invades your network. According to a joint study by the U.S. Federal Bureau of Investigation and the Computer Security Institute, the number and severity of successful corporate hacks is increasing dramatically, particularly intrusions by company insiders. In one study, 250 Fortune 1000 companies reported losses totaling US$137 million in 1997 — an increase of 37 percent over the previous year.

Making an executive commitment to regularly testing, validating, and refreshing your business continuity program can protect your company against perhaps the greatest risk of all — complacency. In the current environment of rapid business and technology change, even the smallest alteration to a critical application or system within your enterprise or supply chain can cause an unanticipated failure, impacting your business continuity. Effective business protection planning addresses not only what you need today, but what you will need tomorrow and into the future.

1.2 Using a SAN for business continuance

Although some of the concepts that we detail purely apply to only the SAN environment, there are general considerations that need to be taken into account in any environment. Any company that is serious about business continuance will have considered and applied processes or procedures to take into account any of the eventualities that may occur, such as those listed in Figure 1-1.

A/C Failure
Acid Leak
Asbestos
Bomb Threat
Bomb Blast
Brown Out
Burst Pipe
Cable Cut
Chemical Spill
CO Fire
Condensation
Construction
Coolant Leak
Cooling Tower Leak
Corrupted Data
Diesel Generator
Earthquake
Electrical Short
Epidemic
Evacuation
Explosion
Fire
Flood
Fraud
Frozen Pipes
Hacker
Hail Storm
Halon Discharge
Human Error
Humidity
Hurricane
HVAC Failure
H/W Error
Ice Storm
Insects
Lightening
Logic Bomb
Lost Data
Low Voltage
Microwave Fade
Network Failure
PCB Contamination
Plane Crash
Power Outage
Power Spike
Power Surge
Programmer Error
Raw Sewage
Relocation Delay
Rodents
Roof Cave In
Sabotage
Shotgun Blast
Shredded Data
Sick building
Smoke Damage
Snow Storm
Sprinkler Discharge
Static Electricity
Strike Action
S/W Error
S/W Ransom
Terrorism
Theft
Toilet Overflow
Tornado
Train Derailment
Transformer File
Tsunami
UPS Failure
Vandalism
Vehicle Crash
Virus
Water (Various)
Wind Storm
Volcano

Figure 1-1 Business outage causes

Some of these problems are not necessarily common to all regions throughout the world, but they should be considered nonetheless, even if only to dismiss the eventuality that they may happen. Careful consideration will result in a deeper understanding of what is likely to cause a business outage, rather than just adopting an attitude that says “it will not happen to me”. After all, remember that the Titanic was unsinkable.

1.2.1 SANs and business continuance

So why would the risk increase if you were to implement a SAN in your environment? The short answer is that it may not increase the risk. It may expose you to more risk over a greater area, for example, the SCSI 25 m restriction means that a small bomb planted in the correct position would do quite nicely. If you are using a SAN for distance solutions, then it might be necessary to increase the size of the bomb, or plant many more of them, to cause the same effect.

What a SAN means is that you now are beginning to explore the potential for ensuring that your business can actually continue in the wake of a disaster. It may be able to do this by:

- Providing for greater operational distances
- Providing mirrored storage solutions for local disasters
- Providing failover support for local disasters
- Providing remote vaulting anywhere in the world
- Providing high availability file serving functionality
- Providing the ability to avoid space outage situations for higher availability

If we are to take the simple example of distance, what a SAN will allow you to do is to break the SCSI distance barrier. Does this in itself make you any safer? Of course it doesn't. Does it give you an opportunity to minimize the risk to your business. Of course it does.

It is up to you if you decide to use that to your advantage, or ignore it and the other benefits that it may bring to your business. One thing is certain though; if you don't exploit the SAN's potential to its fullest, other people may. Those other people might be your competitors. Does that worry you? If it doesn't, then you may want to stop reading right now, because this redbook is not for you! We are targeting those people that are concerned with unleashing the potential of their SAN, or are interested in seeing what a SAN can do.

But that is not all we will do. We will provide you with as much information as we can, that will cover the data center environment from floor to ceiling and the considerations that you should take to ensure minimal exposure to any outage.

As availability is linked to business continuance and recovery, we will also cover methods that can be employed to ensure that the data in your SAN is available to those that are authorized to access it, and protected from those that aren't.

1.3 SAN business benefits

Today's business environment creates many challenges for the enterprise IT planner. This is a true statement and relates to more than just business continuance, so perhaps now is a good time to look at whether deploying a SAN will solve more than just one problem. It may be an opportunity to look at where you are today and where you want to be in three years' time. Is it better to plan for migration to a SAN from the start, or try to implement one later after other solutions have been considered and possibly implemented? Are you sure that the equipment that you install today will still be usable three years later? Is there any use that you can make of it outside of business continuance? A journey of a thousand miles begins with one step.

In the topics that follow we will remind you of some of the business benefits that SANs can provide. We have identified some of the operational problems that a business faces today, and which could potentially be solved by a SAN implementation.

1.3.1 Storage consolidation and sharing of resources

By enabling storage capacity to be connected to servers at a greater distance, and by disconnecting storage resource management from individual hosts, a SAN enables disk storage capacity to be consolidated. The results can be lower overall costs through better utilization of the storage, lower management costs, increased flexibility, and increased control.

This can be achieved physically or logically, as we explain in the following sections.

Physical consolidation

Data from disparate storage subsystems can be combined on to large, enterprise class shared disk arrays, which may be located at some distance from the servers. The capacity of these disk arrays can be shared by multiple servers, and users may also benefit from the advanced functions typically offered with such subsystems. This may include RAID capabilities, remote mirroring, and instantaneous data replication functions, which might not be available with smaller, integrated disks. The array capacity may be partitioned, so that each server has an appropriate portion of the available gigabytes.

Physical consolidation of storage is shown in Figure 1-2.

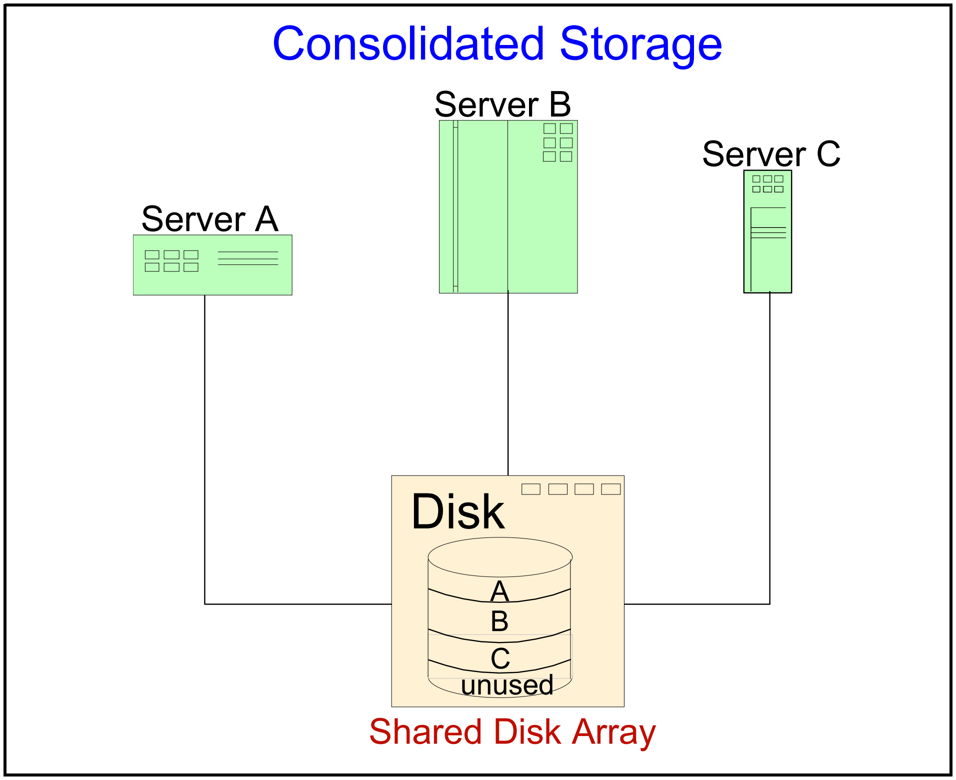


Figure 1-2 Storage consolidation

Available capacity can be dynamically allocated to any server requiring additional space. Capacity not required by a server application can be re-allocated to other servers. This avoids the inefficiency associated with free disk capacity attached to one server not being usable by other servers. Extra capacity may be added, in a non-disruptive manner.

Logical consolidation

It is possible to achieve shared resource benefits from the SAN, but without moving existing equipment. A SAN relationship can be established between a client and a group of storage devices that are not physically co-located (excluding devices which are internally attached to servers). A logical view of the combined disk resources may allow available capacity to be allocated and re-allocated between different applications running on distributed servers, to achieve better utilization. Consolidation is covered in greater depth in *IBM Storage Solutions for Server Consolidation*, SG24-5355.

In Figure 1-3 we show a logical consolidation of storage.

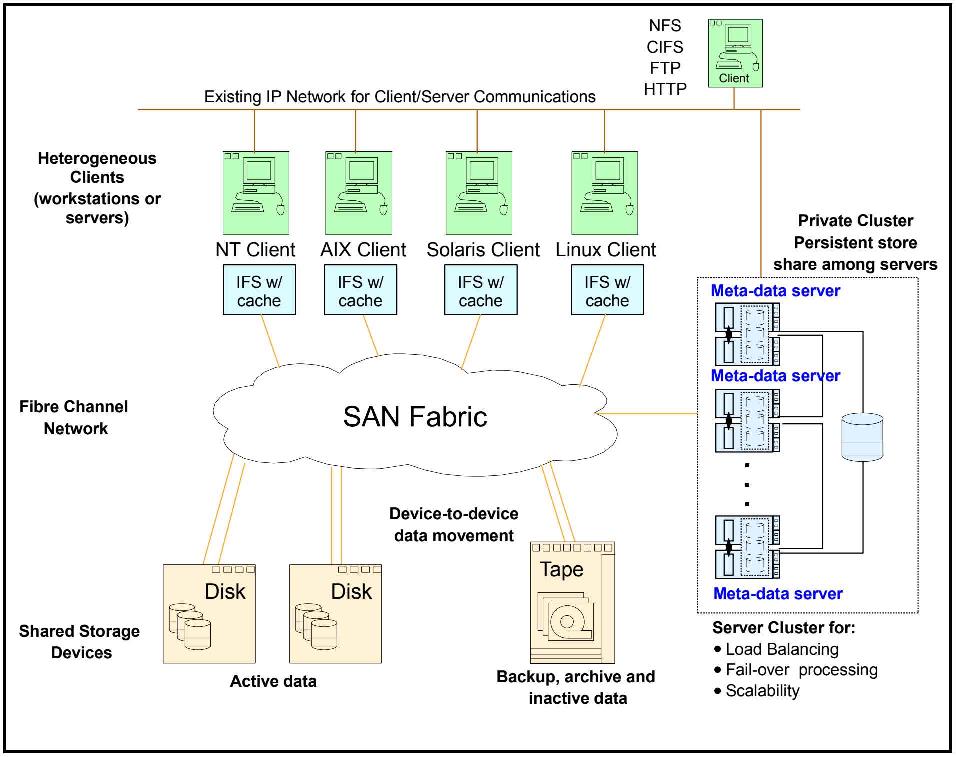


Figure 1-3 Logical storage consolidation

1.3.2 Data sharing

The term “data sharing” is used somewhat loosely by users and some vendors. It is sometimes interpreted to mean the replication of files or databases to enable two or more users, or applications, to concurrently use separate copies of the data. The applications concerned may operate on different host platforms. A SAN may ease the creation of such duplicated copies of data using facilities such as remote mirroring.

Data sharing may also be used to describe multiple users accessing a single copy of a file. This could be called “true data sharing”. In a homogeneous server environment, with appropriate application software controls, multiple servers may access a single copy of data stored on a consolidated storage subsystem.

If attached servers are heterogeneous platforms (for example, with a mix of UNIX and Windows® NT), sharing of data between such unlike operating system environments is complex. This is due to differences in file systems, data formats, and encoding structures. IBM, however, uniquely offers a true data sharing capability, with concurrent update, for selected heterogeneous server environments, using the Tivoli® SANergy™ File Sharing solution.

The SAN advantage in enabling enhanced data sharing may reduce the need to hold multiple copies of the same file or database. This reduces duplication of hardware costs to store such copies. It also enhances the ability to implement cross enterprise applications, such as e-business, which may be inhibited when multiple data copies are stored.

1.3.3 Non-disruptive scalability for growth

There is an explosion in the quantity of data stored by the majority of organizations. This is fueled by the implementation of applications, such as e-business, e-mail, Business Intelligence, Data Warehouse, and Enterprise Resource Planning. Some industry analysts, such as IDC and Gartner Group, estimate that electronically stored data is doubling every year. In the case of e-business applications, opening the business to the Internet, there have been reports of data growing by more than 10 times annually. This is a nightmare for planners, as it is increasingly difficult to predict storage requirements.

A finite amount of disk storage can be connected physically to an individual server due to adapter, cabling, and distance limitations. With a SAN, new capacity can be added as required, without disrupting ongoing operations. SANs enable disk storage to be scaled independently of servers.

1.3.4 Improved backup and recovery

With data doubling every year, what effect does this have on the backup window? Backup to tape, and recovery, are operations which are problematic in the parallel SCSI or LAN based environments. For disk subsystems attached to specific servers, two options exist for tape backup. Either it must be done onto a server attached tape subsystem, or by moving data across the LAN.

Tape pooling

Providing tape drives to each server is costly, and also involves the added administrative overhead of scheduling the tasks, and managing the tape media. SANs allow for greater connectivity of tape drives and tape libraries, especially at greater distances. Tape pooling is the ability for more than one server to logically share tape drives within an automated library. This can be achieved by software management, using tools, such as Tivoli Storage Manager; or with tape libraries with outboard management, such as the IBM 3494.

LAN-free and server-free data movement

Backup using the LAN moves the administration to centralized tape drives or automated tape libraries. However, at the same time, the LAN experiences very high traffic volume during the backup or recovery operations, and this can be extremely disruptive to normal application access to the network. Although backups can be scheduled during non-peak periods, this may not allow sufficient time. Also, it may not be practical in an enterprise which operates in multiple time zones.

We illustrate loading the IP network in Figure 1-4.

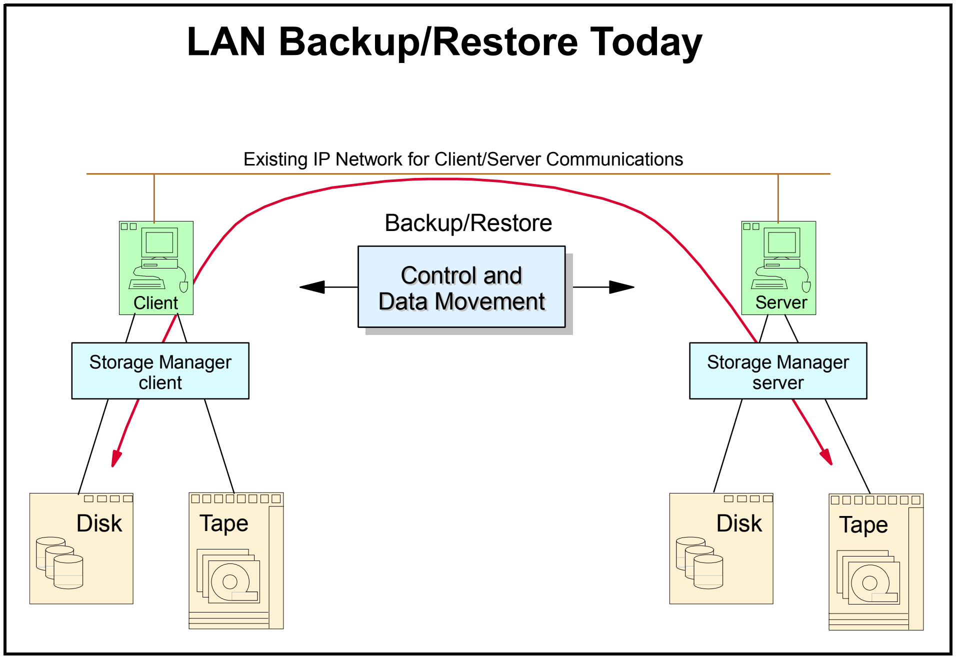


Figure 1-4 Loading the IP network

SAN provides the solution, by enabling the elimination of backup and recovery data movement across the LAN. Fibre Channel's high bandwidth and multi-path switched fabric capabilities enables multiple servers to stream backup data concurrently to high speed tape drives. This frees the LAN for other application traffic. The IBM Tivoli software solution for LAN-free backup offers the capability for clients to move data directly to tape using the SAN. A future enhancement to be provided by IBM Tivoli will allow data to be read directly from disk to tape (and tape to disk), bypassing the server. This solution is known as server-free backup.

1.3.5 High performance

Applications benefit from the more efficient transport mechanism of Fibre Channel. Currently, Fibre Channel transfers data at 200 MB/s, several times faster than typical SCSI capabilities, and many times faster than standard LAN data transfers. Future implementations of Fibre Channel at 400 and 800 MB/s have been defined, offering the promise of even greater performance benefits in the future. Indeed, prototypes of storage components which meet the 2 Gigabit transport specification are already in existence.

The elimination of conflicts on LANs, by removing storage data transfers from the LAN to the SAN, may also significantly improve application performance on servers.

1.3.6 High availability server clustering

Reliable and continuous access to information is an essential prerequisite in any business. As applications have shifted from robust mainframes to the less reliable client/file server environment, so have server and software vendors developed high availability solutions to address the exposure. These are based on clusters of servers. A cluster is a group of independent computers managed as a single system for higher availability, easier manageability, and greater scalability. Server system components are interconnected using specialized cluster interconnects, or open clustering technologies, such as Fibre Channel - Virtual Interface mapping.

Complex software is required to manage the failover of any component of the hardware, the network, or the application. SCSI cabling tends to limit clusters to no more than two servers. A Fibre Channel SAN allows clusters to scale to 4, 8, 16, and even to 100 or more servers, as required, to provide very large shared data configurations, including redundant pathing, RAID protection, and so on. Storage can be shared, and can be easily switched from one server to another. Just as storage capacity can be scaled non-disruptively in a SAN, so can the number of servers in a cluster be increased or decreased dynamically, without impacting the storage environment.

1.3.7 Improved disaster tolerance

Advanced disk arrays, such as IBM Enterprise Storage Server (ESS), provide sophisticated functions, like Peer-to-Peer Remote Copy services, to address the need for secure and rapid recovery of data in the event of a disaster. Failures may be due to natural occurrences, such as fire, flood, or earthquake; or to human error. A SAN implementation allows multiple open servers to benefit from this type of disaster protection, and the servers may even be located some distance (up to 10 km) from the disk array which holds the primary copy of the data. The secondary site, holding the mirror image of the data, may be located up to a further 100 km from the primary site.

IBM has also announced Peer-to-Peer Copy capability for its Virtual Tape Server (VTS). This will allow VTS users to maintain local and remote copies of virtual tape volumes, improving data availability by eliminating all single points of failure.

1.3.8 Allow selection of “best of breed” storage

Internal storage, purchased as a feature of the associated server, is often relatively costly. A SAN implementation enables storage purchase decisions to be made independently of the server. Buyers are free to choose the best of breed solution to meet their performance, function, and cost needs. Large capacity external disk arrays may provide an extensive selection of advanced functions. For instance, the ESS includes cross platform functions, such as high performance RAID 5, Peer-to-Peer Remote Copy, Flash Copy, and functions specific to S/390®, such as Parallel Access Volumes (PAV), Multiple Allegiance, and I/O Priority Queuing. This makes it an ideal SAN attached solution to consolidate enterprise data.

Client/server backup solutions often include attachment of low capacity tape drives, or small automated tape subsystems, to individual PCs and departmental servers. This introduces a significant administrative overhead as users, or departmental storage administrators, often have to control the backup and recovery processes manually. A SAN allows the alternative strategy of sharing fewer, highly reliable, powerful tape solutions, such as the IBM Magstar® family of drives and automated libraries, between multiple users and departments.

1.3.9 Ease of data migration

Data can be moved non-disruptively from one storage subsystem to another using a SAN, without server intervention. This may greatly ease the migration of data associated with the introduction of new technology, and the retirement of old devices.

1.3.10 Reduced total costs of ownership

Expenditure on storage today is estimated to be in the region of 50% of a typical IT hardware budget. Some industry analysts expect this to grow to as much as 75% by the end of the year 2002. IT managers are becoming increasingly focused on controlling these growing costs.

Consistent, centralized management

As we have shown, consolidation of storage can reduce wasteful fragmentation of storage attached to multiple servers. It also enables a single, consistent data and storage resource management solution to be implemented, such as IBM StorWatch™ tools, combined with software such as Tivoli Storage Network Manager, Tivoli Storage Manager, and Tivoli SAN Manager, which can reduce costs of software and human resources for storage management.

Reduced hardware costs

By moving data to SAN attached storage subsystems, the servers themselves may no longer need to be configured with native storage. In addition, the introduction of LAN-free and server-free data transfers largely eliminate the use of server cycles to manage housekeeping tasks, such as backup and recovery, and archive and recall. The configuration of what might be termed “thin servers” therefore might be possible, and this could result in significant hardware cost savings to offset against costs of installing the SAN fabric.

1.3.11 Storage resources match e-business enterprise needs

By eliminating islands of information, typical of the client/server model of computing, and introducing an integrated storage infrastructure, SAN solutions match the strategic needs of today’s e-business.

We show this in Figure 1-5.

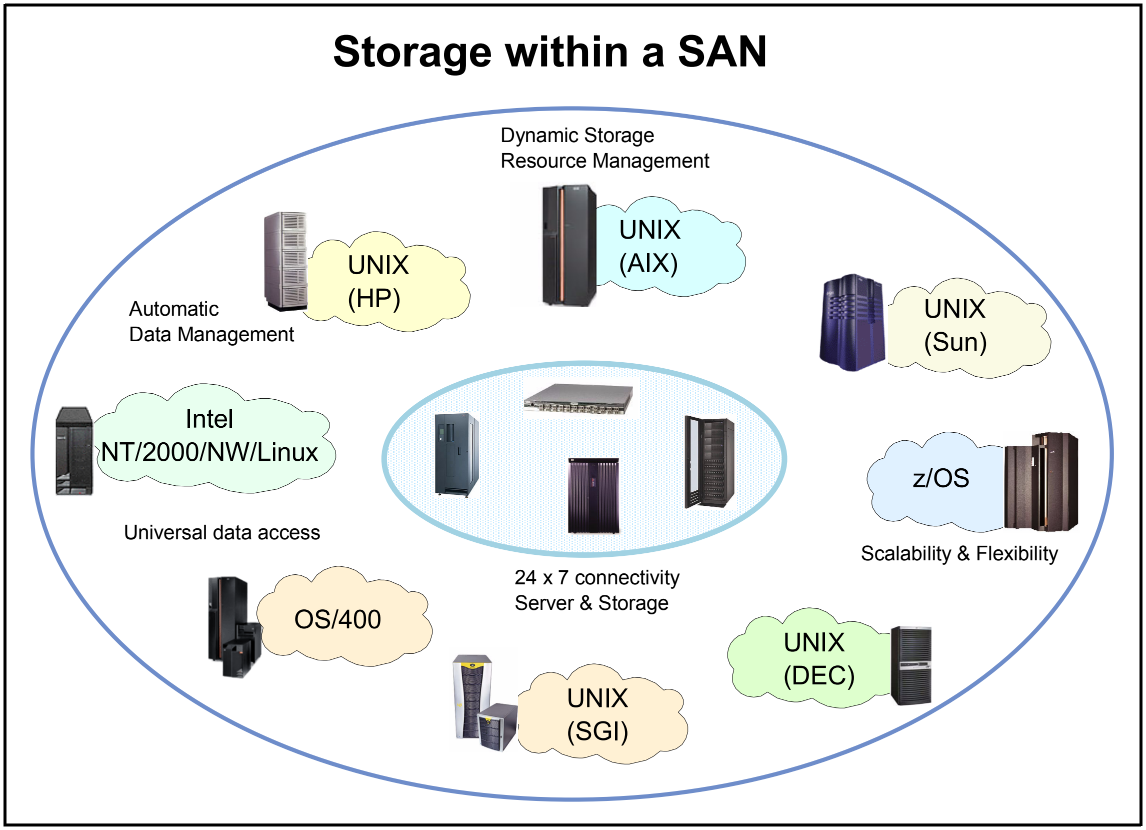


Figure 1-5 SAN total storage solutions

A well designed, well thought out SAN can bring many benefits, and not only those related to business continuance. Utilizing the storage network will be key to the storage and successful retrieval of data in the future, and the days of server centric storage are rapidly becoming a distant memory.

2

SAN fabric components

In this chapter we describe the Fibre Channel products that are used and are likely to be encountered in an IBM Enterprise SAN implementation. This does not mean that you cannot implement other SAN compatible products, including those from other vendors, but the interoperability agreement must be clearly documented and agreed upon.

Fibre Channel is an open standard communications and transport protocol as defined by ANSI (Committee X3T11) and operates over copper and fiber optic cabling at distances of up to 10 kilometers. IBM's implementation is in fiber optic cabling and will be referred to as Fibre Channel cabling, or FC cabling, in this redbook.

Fibre or Fiber?: Fibre Channel was originally designed to support fiber optic cabling only. When copper support was added, the committee decided to keep the name in principle but change its spelling from fiber to fibre. When referring to specific cabling, the correct American English spelling of fiber should be used.

2.1 ASIC technology

Today's hardware designers are required to balance requirements for performance and special features against steadily increasing pressure on design-cycle time, flexibility, and cost. Rapid advances in technology, library design, and design automation have made application specific integrated circuit (ASIC) technology an increasingly viable choice for many applications.

This section describes the common fabric electronics such as ASIC and its predefined set of elements, such as logic functions, I/O circuits, memory arrays and backplane.

The switch and director electronics consist of a system board and multiple port cards respectively, incorporating the Fibre Channel port interfaces, switching mechanism, embedded switch control processor, and support logic for the embedded processor logic.

The application-specific integrated circuit or commonly known as ASIC provides four Fibre Channel ports that may be used to connect to external N_Ports (such as an F_Port or FL_Port), external loop devices (such as an FL_Port), or to other switches (such as an E_Port). The ASIC contains the Fibre Channel interface logic, message/buffer queuing logic, and receive buffer memory for the on-chip ports, as well as other support logic.

2.2 Fiber optic interconnects

In Fibre Channel technology, frames are moved from source to destination using gigabit transport, which is a requirement to achieve fast transfer rates. To communicate with gigabit transport, both sides have to support this type of communication. This can be accomplished by installing this feature into the device or by using specially designed interfaces which can convert other communication transport into gigabit transport. Gigabit transport can be used in a copper or fiber optic infrastructure. We recommend that you consider using a fiber optic implementation if you need to avoid the distance limitation of SCSI, or are likely to in the future.

Nowadays, fibre optic implementations are much more common due to the ease of use and flexibility that it offers. With earlier Fibre Channel implementations, the cost of the copper infrastructure was more attractive, but this is not as significant an issue today.

The interfaces that are used to convert the internal communication transport of gigabit transport are as follows:

- Small Form Factor Transceivers (SFF)
- Gigabit Interface Converters (GBIC)
- Gigabit Link Modules (GLM)
- 1x9 transceivers
- Media Interface Adapters (MIA)

We provide a brief description of the types of cables and connectors, and their functions in the following topics.

2.2.1 Small Form Factor Optical Transceivers

The IBM 1063 Mb/s up to 2125 Mb/s Small Form Factor (SFF) serial optical converters are the next generation of laser-based, optical transceivers for a wide range of networking applications requiring high data rates. The transceivers, which are designed for increased densities, performance, and reduced power, are well-suited for Gigabit Ethernet, Fibre Channel, and 1394b applications (see Figure 2-1).

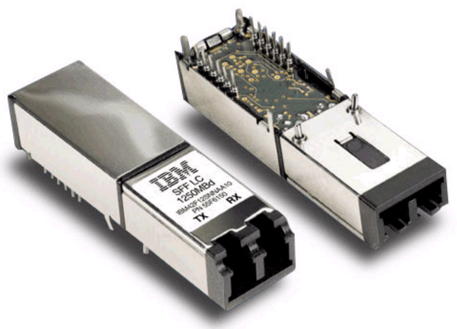


Figure 2-1 Small Form Factor Transceiver

The SFF optical transceivers use short wavelength and long wavelength lasers and are available in pin-through-hole (PTH) or hot-pluggable versions.

The small dimensions of the SFF optical transceivers are ideal in switches and other products where many transceivers have to be configured in a small space. Using these SFF devices, manufacturers can increase the density of transceivers on a board, compared with what was possible using previous optical transceiver technologies. This device is flexible, self-configuring for 100 MB/s or 200 MB/s transmission rates for current or future speeds, providing a seamless transition. Its enhanced design features include frequency agility, reduced power consumption, and lower cost transmission.

The SFF serial optical transceivers are integrated fiber-optic transceivers providing a high-speed serial electrical interface for connecting processors, switches, and peripherals through an optical fiber cable. In the Gigabit Ethernet environment, for example, these transceivers can be used in local area network (LAN) switches or hubs, as well as in interconnecting processors. In SANs, they can be used for transmitting data between peripheral devices and processors.

The SFF optical transceivers use short wavelength and long wavelength lasers that enable cost-effective data transmission over optical fibers at distances of 500 m up to 10 km. They are designed to connect easily to a system card through an industry-standard connector. Multi-mode optical fiber cables, terminated with industry-standard LC connectors, can be used as illustrated in Figure 2-2.

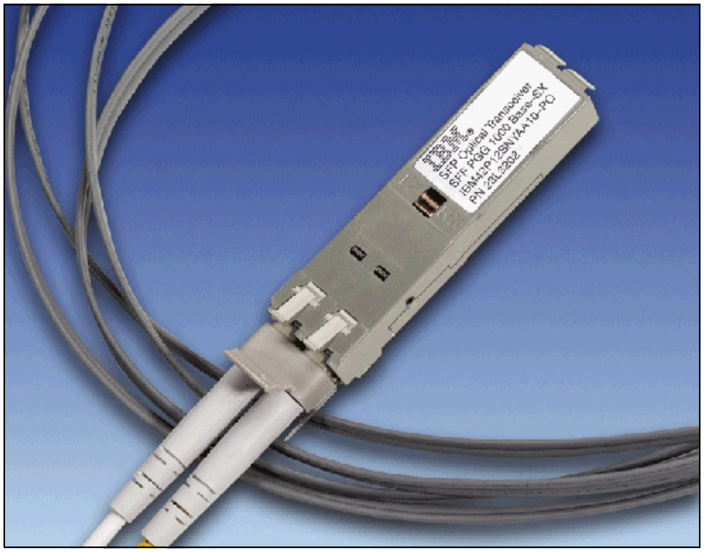


Figure 2-2 SFF hot-pluggable transceiver (SFP) with LC connector fiber cable

The distances that can be achieved using the SFF short wavelength and long wavelength are listed in Table 2-1.

Table 2-1 Distances using SFF-based fiber optics

Type of fiber	**SWL**	**LWL**
9/125 µm Optical Fiber	n/a	• Distance for 100 MB/s version: 2 m - 10 km • Distance for 1.250 Gb/s version: 2 m - 5 km • Distance for 2.125 Gb/s version: 2 m - 10 km

Type of fiber	SWL	LWL
50/125 µm Optical Fiber	• Distance for 1.0625 Gb/s version: 2 - 500 m • Distance for 1.250 Gb/s version: 2 - 550 m • Distance for 2.125 Gb/s version: 2 - 300 m	2 - 550 m
62.5/125 µm Optical Fiber	• Distance for 1.0625 Gb/s version: 2 - 300 m • Distance for 1.250 Gb/s version: 2 - 275 m • Distance for 2.125 Gb/s version: 2 - 150 m	2 - 550 m

The distances shown are not necessarily the supported distances, and this will have to be verified with the fiber transport installer.

SFP: The Small Form Factor Hot-Pluggable module is also known as SFP. The IBM SFF optical transceiver is offered with an LC connector due to its robustness, increased transmission performance, better EMI, virtually no optical or electrical cross talk, and less jitter, with the primary objective being to ensure reliability, serviceability, and availability.

An SFF is not always hot-pluggable, whereas an SFP is.

2.2.2 Gigabit Interface Converters

The IBM 1063 Mb/s and 1250 Mb/s Gigabit Interface Converters (GBICs) are laser-based, hot-pluggable, data communications transceivers for a wide range of networking applications requiring high data rates. The transceivers, which are designed for ease of configuration and replacement, are well-suited for Gigabit Ethernet, Fibre Channel, and 1394b applications.

The 1063 Mb/s GBIC and 1250 Mb/s GBIC are available in both short wavelength and long wavelength versions, providing configuration flexibility. Users can easily add a GBIC in the field to accommodate a new configuration requirement or replace an existing device to allow for increased availability.

The 1063 Mb/s GBIC and 1250 Mb/s GBIC are integrated fiber-optic transceivers providing a high-speed serial electrical interface for connecting processors, switches, and peripherals through an optical fiber cable. In the Gigabit Ethernet environment, for example, these transceivers can be used in local area network (LAN) switches or hubs, as well as in interconnecting processors. In SANs they can be used for transmitting data between peripheral devices and processors.

The GBICs use lasers that enable cost-effective data transmission over optical fibers at distances of up to 10 km. These compact, hot-pluggable, field-replaceable modules are designed to connect easily to a system card through an industry-standard connector. Single-mode or multi-mode optical fiber cables, terminated with industry-standard SC connectors, can be used.

Also available now are 2125 Mb/s and 2500 Mb/s GBICs (referred to below as 2 Gb/s GBIC). We have included below the distance capabilities for each of the different types of GBICs.

There are two types of connections on the service side, namely, DB-9 and HSSDC. The fiber-optic type has two modes of operation. The difference between them is in the laser wave length. The two modes are:

- Short wavelength mode: SWL
- Long wavelength mode: LWL

The distances that can be achieved using both the 1 Gb/s-based GBICs are shown in Table 2-2.

Table 2-2 Distance using 1 Gb/s GBIC based fiber optics

Type of fiber	SWL	LWL
9/125 µm Optical Fiber	n/a	10 km
50/125 µm Optical Fiber	2 - 550 m	2 - 550 m
62.5/125 µm Optical Fiber	2 - 300 m	2 - 550 m

The distances that can be achieved using both the 2Gb/s based GBICs are shown in Table 2-3.

Table 2-3 Distance using 2 Gb/s GBIC based fiber-optics

Type of fiber	SWL	LWL
9/125 µm Optical Fiber	n/a	10 km
50/125 µm Optical Fiber	2 - 300 m	2 - 550 m
62.5/125 µm Optical Fiber	2 - 150 m	2 - 550 m

The standard dual SC plug is used to connect to the fiber optic cable. This is shown in Figure 2-3.

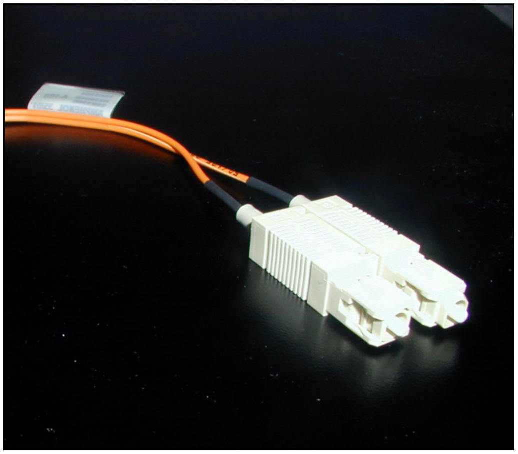


Figure 2-3 Dual SC fiber-optic plug connector

GBICs are usually hot-pluggable, easy to configure and replace. On the optical side they use low-loss, SC type, push-pull, optical connectors. They are mainly used in hubs, switches, directors, and gateways.

Shortwave (or multi-mode) GBICs are usually color coded beige with a black exposed surface; and longwave (or single-mode) GBICs are usually color coded blue with blue exposed surfaces.

The transfer rates typically range from 1063 Mb/s,1250 Mb/s, 2125 Mb/s, or 2500 Mb/s. A GBIC is shown in Figure 2-4.

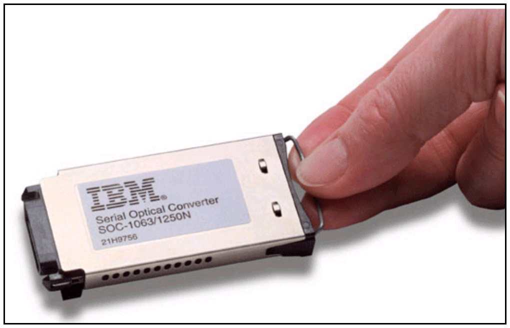


Figure 2-4 Gigabit Interface Converter

The selection of a GBIC for SAN interconnection is just as important a consideration as choosing a hub or a switch, and should not be overlooked or taken lightly.

2.2.3 Gigabit Link Modules

Gigabit Link Modules (GLMs) — sometimes referred to as Gigabaud Link Modules) — were used in early Fibre Channel applications. GLMs are a low cost alternative to GBICs, but they sacrifice the ease of use and hot-pluggable installation and replacement characteristics that GBICs offer. This means that you need to power down the device for maintenance, replacement, or repair.

GLMs enable computer manufacturers to integrate low-cost, high-speed fiber optic communications into devices. They use the same fiber optic for the transport of optical signal as GBICs. GLMs also use two types of lasers, SWL and LWL, to transport the information across the fiber optic channel. The transfer rates that are available are 266 Mb/s and 1063 Mb/s.

The 266 Mb/s and 1063 Mb/s GLM cards support continuous, full-duplex communication. The GLM converts encoded data that has been serialized into pulses of laser light for transmission into the optical fiber. A GLM at a second optical link, running at the same speed as the sending GLM, receives these pulses, along with the requisite synchronous clocking signals.

With 1063 Mb/s you can achieve the distances listed in Table 2-2, “Distance using 1 Gb/s GBIC based fiber optics” on page 24.

A GLM is shown in Figure 2-5.

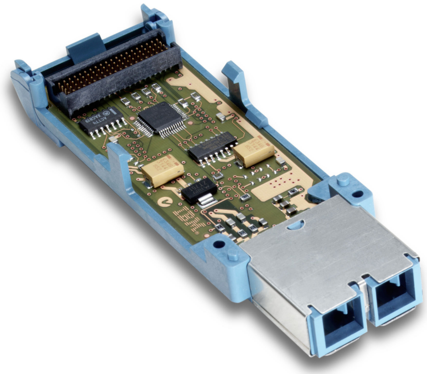


Figure 2-5 Gigabit Link Module

2.2.4 Media Interface Adapters

Media Interface Adapters (MIAs) can be used to facilitate conversion between optical and copper interface connections. Typically, MIAs are attached to host bus adapters, but they can also be used with switches and hubs. If a hub or switch only supports copper or optical connections, MIAs can be used to convert the signal to the appropriate media type, copper or optical.

An MIA is shown in Figure 2-6.

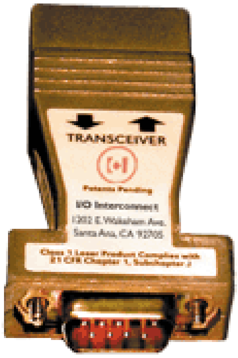


Figure 2-6 Media Interface Adapter

2.2.5 1x9 transceivers

Some switch manufacturers prefer to use 1x9 transceivers for providing SC connection to their devices. 1x9 transceivers (Figure 2-7) have some advantages over GBICs:

- Easier to cool
- Better air flow
- More reliable (2.5 times that of a GBIC)

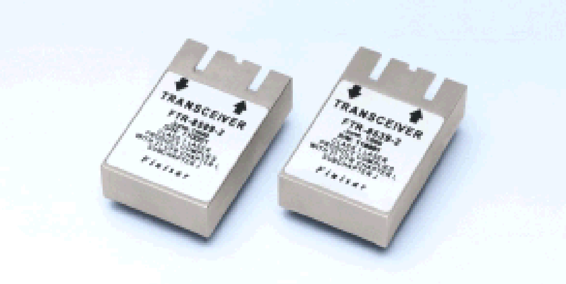


Figure 2-7 1x9 transceivers

2.2.6 Fibre Channel adapter cable

The LC-SC adapter cable attaches to the end of an LC-LC cable to support SC device connections. A combination of one LC/LC fiber cable and one LC/SC adapter cable is required for each connection. This is used to connect from some of the older 1 Gb/s devices to a 2 Gb/s capable and LC interface-based SAN.

Shown in Figure 2-6 is a Fibre Channel adapter cable.

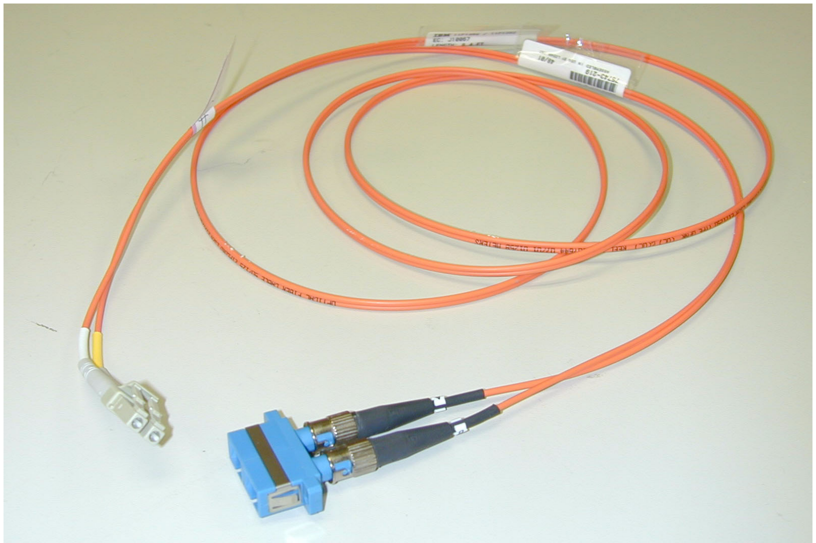


Figure 2-8 Fibre Channel adapter cable

2.3 Fibre Channel ports

Before we look at the concepts that make up the SAN topology, we first introduce the terminology that is important to understand when joining a discussion on SAN. At various stages throughout this chapter, we then begin to describe some of the most common items that are met.

2.3.1 Port types

These are the types of Fibre Channel ports that are likely to be encountered:

- **E_Port:** This is an expansion port. A port is designated an E_Port when it is used as an inter switch expansion port (ISL) to connect to the E_Port of another switch, to enlarge the switch fabric.
- **F_Port:** This is a fabric port that is not loop capable. It is used to connect an N_Port point-to-point to a switch.
- **FL_Port:** This is a fabric port that is loop capable. It is used to connect NL_Ports to the switch in a public loop configuration.
- **G_Port:** This is a generic port that can operate as either an E_Port or an F_Port. A port is defined as a G_Port after it is connected but has not received response to *loop* initialization or has not yet completed the *link* initialization procedure with the adjacent Fiber Channel device.
- **L_Port:** This is a loop capable node or switch port.
- **U_Port:** This is a universal port. A more generic switch port than a G_Port. It can operate as either an E_Port, F_Port, or FL_Port. A port is defined as a U_Port when it is not connected or has not yet assumed a specific function in the fabric.
- **N_Port:** This is a node port that is not loop capable. It is used to connect an equipment port to the fabric.
- **NL_Port:** This is a node port that is loop capable. It is used to connect an equipment port to the fabric in a loop configuration through an L_Port or FL_Port.

Figure 2-9 represents the most commonly encountered Fibre Channel port types.

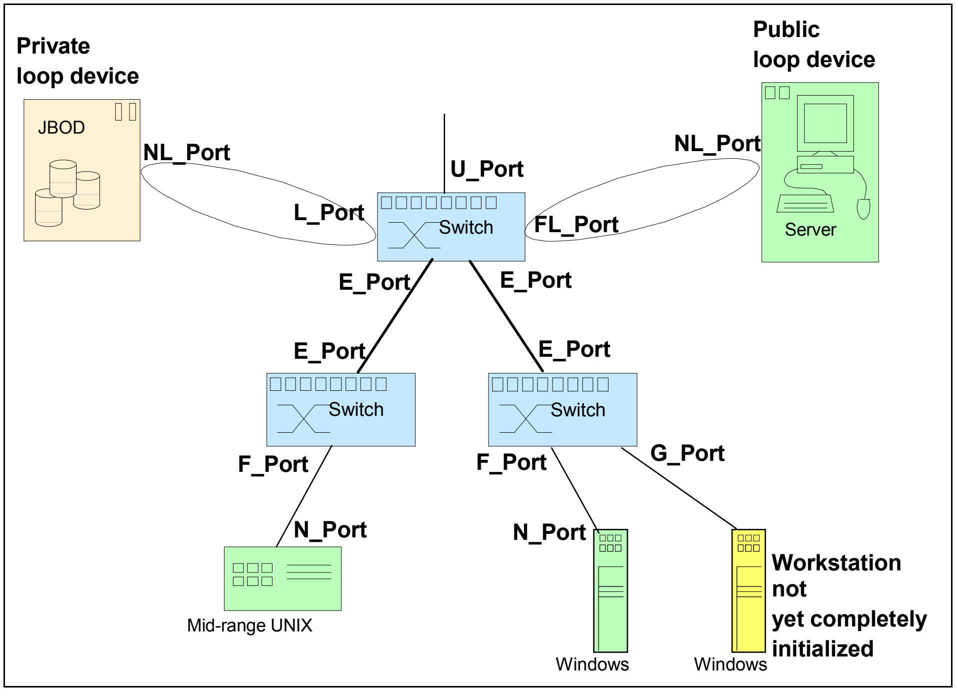


Figure 2-9 Fibre Channel port types

2.4 SAN topologies

Fibre Channel provides three distinct interconnection topologies. By having more than one interconnection option available, a particular application can choose the topology that is best suited to its requirements. The three Fibre Channel topologies are:

- Point-to-point
- Arbitrated loop
- Switched fabric

We discuss these in greater detail in the topics that follow.

2.4.1 Point-to-point

A point-to-point connection is the simplest topology. It is used when there are exactly two nodes, and future expansion is not predicted. There is no sharing of the media, which allows the devices to use the total bandwidth of the link. A simple link initialization is needed before communications can begin.

Fibre Channel is a full duplex protocol, which means both paths simultaneously. Fibre Channel connections based on the 1 Gb standard are able to transmit at 100 MB/s and receive at 100 MB/s simultaneously.

For Fibre Channel connections based on the 2 Gb standard, they can transmit at 200 MB/s and receive at 200 MB/s simultaneously.

Illustrated in Figure 2-10 is a simple point-to-point connection.

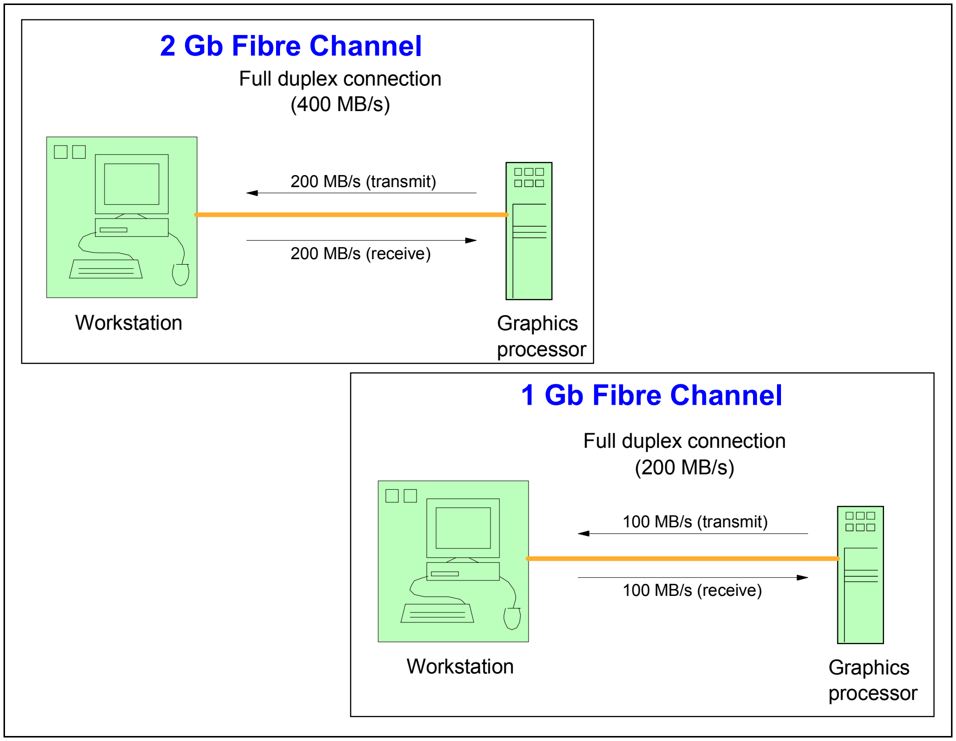


Figure 2-10 Point-to-point

An extension of the point-to-point topology is the logical start topology. This is a collection of point-to-point topology links and both topologies provide full duplex bandwidth.

2.4.2 Arbitrated loop

The second topology is Fibre Channel Arbitrated Loop (FC-AL). FC-AL is more useful for storage applications. It is a loop of up to 126 nodes (NL_Ports) that is managed as a shared bus. Traffic flows in one direction, carrying data frames and primitives around the loop with a total bandwidth of 200 MB/s (or 100 MB/s for a loop based on 1 Gb/s technology).

Using arbitration protocol, a single connection is established between a sender and a receiver, and a data frame is transferred around the loop. When the communication comes to an end between the two connected ports, the loop becomes available for arbitration and a new connection may be established. Loops can be configured with hubs to make connection management easier. A distance of up to 10 km is supported by the Fibre Channel standard for both of these configurations. However, latency on the arbitrated loop configuration is affected by the loop size.

A simple loop, configured using a hub, is shown in Figure 2-11.

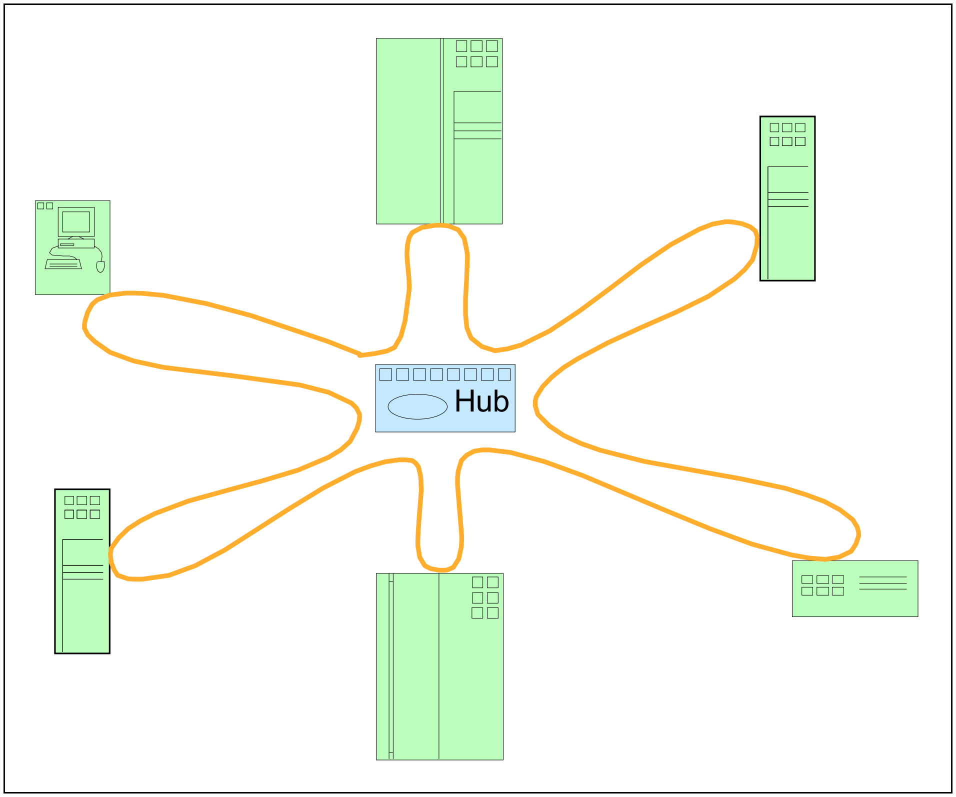


Figure 2-11 Arbitrated loop

Loop protocols

To support the shared behavior of the arbitrated loop, a number of loop-specific protocols are used. These protocols are used to:

- Initialize the loop and assign addresses.
- Arbitrate for access to the loop.
- Open a loop circuit with another port in the loop.
- Close a loop circuit when two ports have completed their current use of the loop.
- Implement the access fairness mechanism to ensure that each port has an opportunity to access the loop.

Loop initialization

Loop initialization is a necessary process for the introduction of new participants on to the loop. Whenever a loop port is powered on or initialized, it executes the loop initialization primitive (LIP) to perform loop initialization. Optionally, loop initialization may build a positional map of all the ports on the loop. The positional map provides a count of the number of ports on the loop, their addresses and their position relative to the loop initialization master.

Following loop initialization, the loop enters a stable monitoring mode and begins with normal activity. An entire loop initialization sequence may take only a few milliseconds, depending on the number of NL_Ports attached to the loop. Loop initialization may be started by a number of causes. One of the most likely reasons for loop initialization is the introduction of a new device. For instance, an active device may be moved from one hub port to another hub port, or a device that has been powered on could re-enter the loop.

A variety of ordered sets have been defined to take into account the conditions that an NL_Port may sense as it starts the initialization process. These ordered sets are sent continuously while a particular condition or state exists. As part of the initialization process, loop initialization primitive sequences (referred to collectively as LIPs) are issued. As an example, an NL_Port must issue at least three identical ordered sets to start initialization. An ordered set transmission word always begins with the special character K28.5.

Once these identical ordered sets have been sent, and as each downstream device receives the LIP stream, devices enter a state known as open-init. This causes the suspension of any current operation and enables the device for the loop initialization procedure. LIPs are forwarded around the loop until all NL_Ports are in an open-init condition.

At this point, the NL_Ports need to be managed. In contrast to a Token-Ring, the Arbitrated Loop has no permanent master to manage the topology.

Therefore, loop initialization provides a selection process to determine which device will be the temporary loop master. After the loop master is chosen it assumes the responsibility for directing or managing the rest of the initialization procedure. The loop master also has the responsibility for closing the loop and returning it to normal operation.

Selecting the loop master is carried out by a subroutine known as the Loop Initialization Select Master (LISM) procedure. A loop device can be considered for temporary master by continuously issuing LISM frames that contain a port type identifier and a 64-bit World-Wide Name. For FL_Ports the identifier is x'00' and for NL_Ports it is x'EF'.

When a downstream port receives a LISM frame from a upstream partner, the device will check the port type identifier. If the identifier indicates an NL_Port, the downstream device will compare the WWN in the LISM frame to its own. The WWN with the lowest numeric value has priority. If the received frame's WWN indicates a higher priority, that is to say it has a lower numeric value, the device stops its LISM broadcast and starts transmitting the received LISM. Had the received frame been of a lower priority, the receiver would have thrown it away and continued broadcasting its own.

At some stage in proceedings, a node will receive its own LISM frame, which indicates that it has the highest priority, and succession to the throne of temporary loop master has taken place. This node will then issue a special ordered set to indicate to the others that a temporary master has been selected.

Hub cascading

Since an arbitrated loop hub supplies a limited number of ports, building larger loops may require linking another hub. This is called hub cascading. A server with an FC-AL, shortwave, host bus adapter can connect to an FC-AL hub 500 m away. Each port on the hub can connect to an FC-AL device up to 500 m away. Cascaded hubs use one port on each hub for the hub-to-hub connection and this increases the potential distance between nodes in the loop by an additional 500 m. In this topology the overall distance is 1500 m. Both hubs can support other FC-AL devices at their physical locations. Stated distances assume a 50 micron multi-mode cable.

Loops

There are two different kinds of loops: private and public.

- **Private loop:** The private loop does not connect with a fabric, only to other private nodes using attachment points called NL_Ports. A private loop is enclosed and known only to itself. In Figure 2-12 we show a private loop.

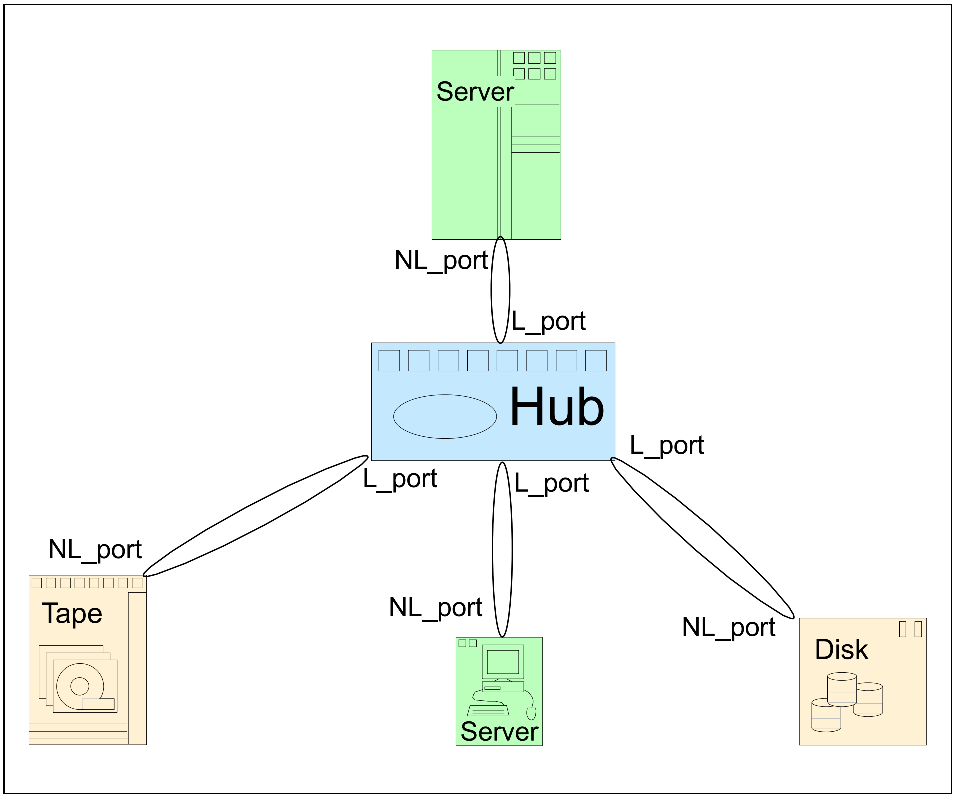


Figure 2-12 Private loop implementation

- **Public loop:** A public loop requires a fabric and has at least one FL_Port connection to a fabric. A public loop extends the reach of the loop topology by attaching the loop to a fabric. Figure 2-13 shows a public loop.

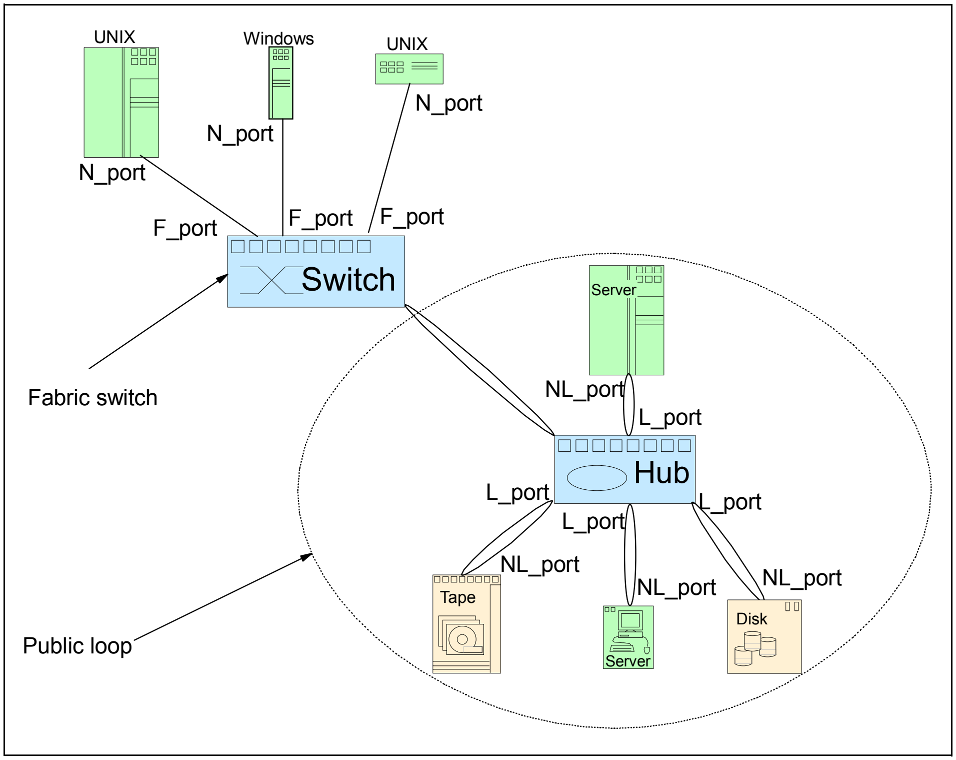


Figure 2-13 Public loop implementation

Arbitration

When a loop port wants to gain access to the loop, it has to arbitrate. When the port wins arbitration, it can open a loop circuit with another port on the loop; a function similar to selecting a device on a bus interface. Once the loop circuit has been opened, the two ports can send and receive frames between each other. This is known as loop tenancy.

If more than one node on the loop is arbitrating at the same time, the node with the lower Arbitrated Loop Physical Address (AL_PA) gains control of the loop. Upon gaining control of the loop, the node then establishes a point-to-point transmission with another node using the full bandwidth of the media. When a node has finished transmitting its data, it is not required to give up control of the loop. This is a channel characteristic of Fibre Channel. However, there is a fairness algorithm, which states that a device cannot regain control of the loop until the other nodes have had a chance to control the loop.

Loop addressing

An NL_Port, like an N_Port, has a 24-bit port address. If no switch connection exists, the two upper bytes of this port address are zeroes (x’00 00’) and referred to as a private loop. The devices on the loop have no connection with the outside world. If the loop is attached to a fabric and an NL_Port supports a fabric login, the upper two bytes are assigned a positive value by the switch. We call this mode a public loop.

As fabric-capable NL_Ports are members of both a local loop and a greater fabric community, a 24-bit address is needed as an identifier in the network. In the case of public loop assignment, the value of the upper two bytes represents the loop identifier, and this will be common to all NL_Ports on the same loop that performed login to the fabric.

In both public and private arbitrated loops, the last byte of the 24-bit port address refers to the arbitrated loop physical address (AL_PA). The AL_PA is acquired during initialization of the loop and may, in the case of fabric-capable loop devices, be modified by the switch during login.

The total number of the AL_PAs available for arbitrated loop addressing is 127. This number is based on the requirements of 8b/10b running disparity between frames.

As a frame terminates with an end-of-frame character (EOF), this will force the current running disparity negative. In the Fibre Channel standard each transmission word between the end of one frame and the beginning of another frame should also leave the running disparity negative. If all 256 possible 8-bit bytes are sent to the 8b/10b encoder, 134 emerge with neutral disparity characters. Of these 134, seven are reserved for use by Fibre Channel. The 127 neutral disparity characters left have been assigned as AL_PAs. Put another way, the 127 AL_PA limit is simply the maximum number, minus reserved values, of neutral disparity addresses that can be assigned for use by the loop. This does not imply that we recommend this amount, or load, for a 200MB/s shared transport, but only that it is possible.

Arbitrated loop will assign priority to AL_PAs, based on numeric value. The lower the numeric value, the higher the priority is. For example, an AL_PA of x’01’ has a much better position to gain arbitration over devices that have a lower priority or higher numeric value. At the top of the hierarchy it is not unusual to find servers, but at the lower end you would expect to find disk arrays.

It is the arbitrated loop initialization that ensures each attached device is assigned a unique AL_PA. The possibility for address conflicts only arises when two separated loops are joined together without initialization.

2.4.3 Logins

There are three different types of logins for Fibre Channel:

- Fabric login
- Port login
- Process login

Here we describe only the port login and the process login. Later, we provide details on the fabric login; you can refer to “Fabric login” on page 44.

Port login

The port login is also known as PLOGI.

A port login is used to establish a session between two N_Ports (devices) and is necessary before any upper level commands or operations can be performed. During the port login, two N_Ports (devices) swap service parameters and make themselves known to each other.

Process login

The process login is also known as PRLI. The process login is used to set up the environment between related processes on an originating N_Port and a responding N_Port. A group of related processes is collectively known as an image pair. The processes involved can be system processes, system images, such as mainframe logical partitions, control unit images, and FC-4 processes. Use of the process login is optional from the perspective of the Fibre Channel FC-2 layer, but may be required by a specific upper-level protocol, as in the case of SCSI-FCP mapping.

We show the Fibre Channel logins in Figure 2-14.

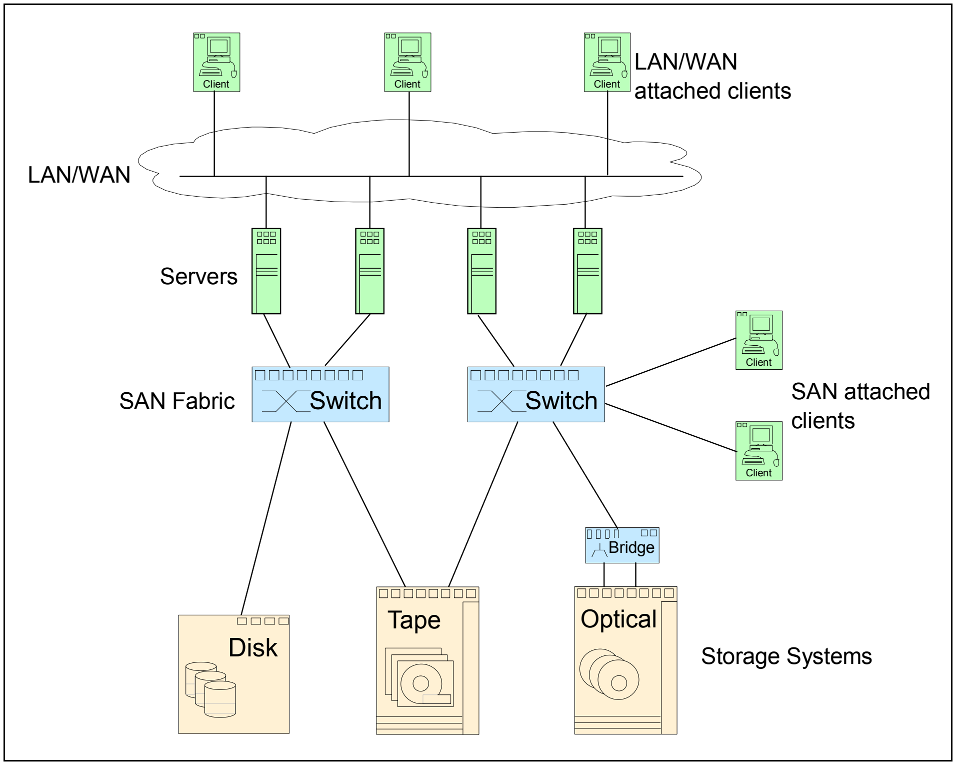


Figure 2-14 Fibre Channel logins

Closing a loop circuit

When two ports in a loop circuit complete their frame transmission, they may close the loop circuit to allow other ports to use the loop. The point at which the loop circuit is closed depends on the higher-level protocol, the operation in progress, and the design of the loop ports.

Supported devices

An arbitrated loop may support a variety of devices, such as:

- Individual Fibre Channel disk drives
- JBOD
- Fibre Channel RAID
- Native Fibre Channel tape sub-systems
- Fibre Channel to SCSI bridges

Broadcast

Arbitrated loop, in contrast to Ethernet, is a non-broadcast transport. When an NL_Port has successfully won the right to arbitration, it will open a target for frame transmission. Any subsequent loop devices in the path between the two will see the frames and forward them on to the next node in the loop.

It is this non-broadcast nature of arbitrated loop, by removing frame handling overhead from some of the loop, which enhances performance.

Distance

As stated before, arbitrated loop is a closed-ring topology. The total distance requirements being determined by the distance between the nodes. At gigabit speeds, signals propagate through fiber-optic media at five nanoseconds per meter and through copper media at four nanoseconds per meter. This is the delay factor.

Calculating the total propagation delay incurred by the loop's circumference is achieved by multiplying the length — both transmit and receive — of copper and fiber-optic cabling deployed by the appropriate delay factor. For example, a single 10 km link to an NL_Port would cause a 50 microsecond (10 km x 5 nanoseconds delay factor) propagation delay in each direction and 100 microseconds in total. This equates to 1 MB/s of bandwidth used to satisfy the link.

Bandwidth

For optical interconnects for SANs, the bandwidth requirements are greatly influenced by the capabilities of:

- The system buses
- Network switches
- The interface adapters that interface with them
- Traffic locality

The exact bandwidth required is somewhat dependent on implementation, but is currently in the range of 100 to 1000 MB/s. Determining bandwidth requirements is difficult, and there is no exact science that can take into account the unpredictability of sporadic bursts of data, for example. Planning bandwidth based on peak requirements could be wasteful. Designing for sustained bandwidth requirements, with the addition of safety margins, may be less wasteful.

2.4.4 Switched fabric

The third topology used in SAN implementations is Fibre Channel Switched Fabric (FC-SW). It applies to directors that support the FC-SW standard, that is, it is not limited to switches as its name suggests. A Fibre Channel fabric is one or more fabric switches in a single, sometimes extended, configuration. Switched fabrics provide full 200 MB/s bandwidth per port (or 100 MB/s for devices based on the older 1 Gb/s infrastructure), compared to the shared bandwidth per port in Arbitrated loop implementations.

If you add a new device into the arbitrated loop, you further divide the shared bandwidth. However, in a switched fabric, adding a new device or a new connection between existing ones actually increases the bandwidth. For example, an 8-port switch (based on 2 Gb/s technology) with three initiators and three targets can support three concurrent 200 MB/s conversations or a total of 600 MB/s throughput (1,200 MB/s if full-duplex applications were available).

A switched fabric configuration is shown in Figure 2-15.

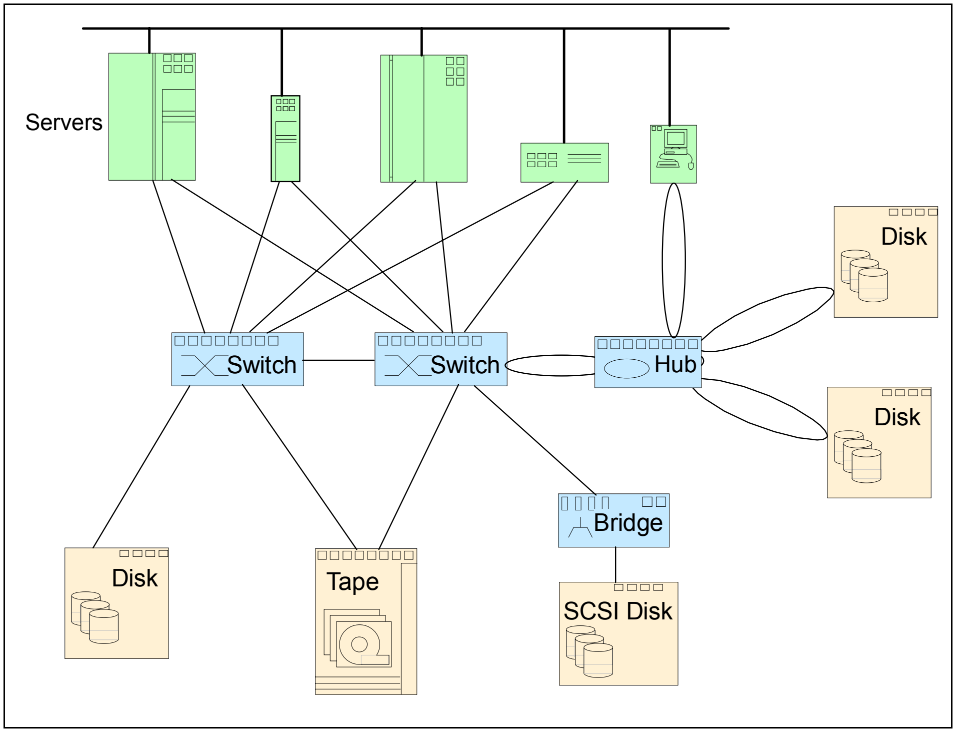


Figure 2-15   Sample switched fabric configuration

Addressing

As we know from “Name and addressing” on page 42, each participant in the Fibre Channel environment has a unique ID, which is called the World Wide Name (WWN). This WWN is a 64-bit address, and if two WWN addresses are put into the frame header, this leaves 16 bytes of data just for identifying destination and source address. So 64-bit addresses can impact routing performance.

Because of this, there is another addressing scheme used in Fibre Channel networks. This scheme is used to address the ports in the switched fabric. Each port in the switched fabric has its own unique 24-bit address. With this 24-bit addressing scheme, we get a smaller frame header, and this can speed up the routing process. With this frame header and routing logic, the Fibre Channel fabric is optimized for high-speed switching of frames.

With a 24-bit addressing scheme, this allows for up to 16 million addresses, which is an address space larger than any practical SAN design in existence in today’s world. This 24-bit address has to somehow be connected to and with the 64-bit address associated with World Wide Names. We explain how this works in the following section.

Name and addressing

The 24-bit address scheme also removes the overhead of manual administration of addresses by allowing the topology itself to assign addresses. This is not like WWN addressing, in which the addresses are assigned to the manufacturers by the IEEE standards committee, and are built in to the device at build time, similar to naming a child at birth. If the topology itself assigns the 24-bit addresses, then somebody has to be responsible for the addressing scheme from WWN addressing to port addressing.

In the switched fabric environment, the switch itself is responsible for assigning and maintaining the port addresses. When the device with its WWN is logging into the switch on a specific port, the switch will assign the port address to that port, and the switch will also maintain the correlation between the port address and the WWN address of the device on that port. This function of the switch is implemented by using a name server.

The name server is a component of the fabric operating system, which runs inside the switch. It is essentially a database of objects in which fabric-attached device registers its values.

Dynamic addressing also removes the potential element of human error in address maintenance, and provides more flexibility in additions, moves, and changes in the SAN.

Port address

A 24-bit port address consists of three parts:

- Domain (bits from 23 to 16)
- Area (bits from 15 to 08)
- Port or arbitrated loop physical address — AL_PA (bits from 07 to 00)

We show how the address is built up in Figure 2-16.

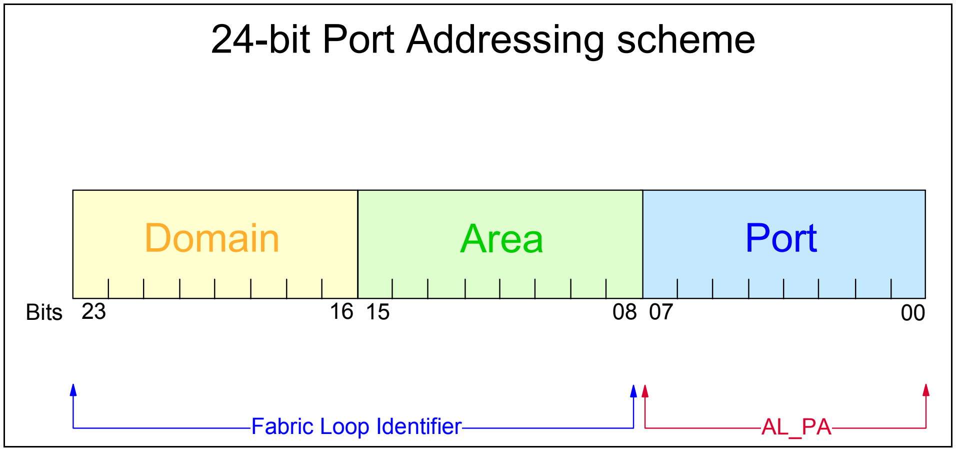


Figure 2-16 Fabric port address

Next we explain the significance of some of the bits that make up the port address:

- **Domain:** The most significant byte of the port address is the domain. This is the address of the switch itself. One byte allows up to 256 possible addresses. Because some of these are reserved (like the one for broadcast) there are only 239 addresses actually available. This means that you can have as many as 239 switches in your SAN environment. The domain number allows each switch to have a unique identifier if you have multiple interconnected switches in your environment.
- **Area:** The area field provides 256 addresses. This part of the address is used to identify the individual FL_Ports supporting loops, or it can be used as the identifier for a group of F_Ports; for example, a card with more ports on it. This means that each group of ports has a different area number, even if there is only one port in the group.
- **Port:** The final part of the address provides 256 addresses for identifying attached N_Ports and NL_Ports.

To arrive at the number of available addresses is a simple calculation based on:

Domain x Area x Ports

This means that there are 239 x 256 x 256 = 15,663,104 addresses available.

Fabric login

After the fabric capable Fibre Channel device is attached to a fabric switch, it will carry out a fabric login (FLOGI).

Similar to port login, FLOGI is an extended link service command that sets up a session between two participants. With FLOGI, a session is created between an N_Port or NL_Port and the switch. An N_Port will send a FLOGI frame that contains its Node Name, its N_Port Name, and service parameters to a well-known address of 0xFFFFFE.

A public loop NL_Port first opens the destination AL_PA 0x00 before issuing the FLOGI request. In both cases the switch accepts the login and returns an accept (ACC) frame to the sender. If some of the service parameters requested by the N_Port or NL_Port are not supported, the switch will set the appropriate bits in the ACC frame to indicate this.

When the N_Port logs in, it uses a 24-bit port address of 0x000000. Because of this, the fabric is allowed to assign the appropriate port address to that device, based on the Domain-Area-Port address format. The newly assigned address is contained in the ACC response frame.

When the NL_Port logs in, a similar process starts, except that the least significant byte is used to assign AL_PA, and the upper two bytes constitute a fabric loop identifier. Before an NL_Port logs in, it will go through the LIP on the loop, which is started by the FL_Port, and from this process it has already derived an AL_PA. The switch then decides if it will accept this AL_PA for this device or not. If not, a new AL_PA is assigned to the NL_Port, which then causes the start of another LIP. This ensures that the switch assigned AL_PA does not conflict with any previously selected AL_PAs on the loop.

After the N_Port or public NL_Port gets its fabric address from FLOGI, it needs to register with the SNS. This is done with port login (PLOGI) at the address 0xFFFFFC. The device may register values for all or just some database objects, but the most useful are its 24-bit port address, 64-bit World Wide Port Name (WWPN), 64-bit World Wide Node Name (WWN), class of service parameters, FC-4 protocols supported, and port type, such as N_Port or NL_Port.

Private devices on NL_Ports

It is easy to explain how the port to World Wide Name address resolution works when a single device from an N_Port is connected to an F_Port, or when a public NL_Port device is connected to FL_Port in the switch. The SNS will add an entry for the device World Wide Name and connects that with the port address which is selected from the selection of free port addresses for that switch. Problems may arise when a private Fibre Channel device is attached to the switch. Private Fibre Channel devices were designed to only work in private loops.

When the arbitrated loop is connected to the FL_Port, this port obtains the highest priority address in the loop to which it is attached (0x00). Then the FL_Port performs a LIP. After this process is completed, the FL_Port registers all devices on the loop with the SNS. Devices on the arbitrated loop use only 8-bit addressing, but in the switched fabric, 24-bit addressing is used. When the FL_Port registers the devices on the loop to the SNS, it adds two most significant bytes to the existing 8-bit address.

The format of the address in the SNS table is 0xPPPPLL, where the PPPP is the two most significant bytes of the FL_Port address and the LL is the device ID on the arbitrated loop which is connected to this FL_Port. Modifying the private loop address in this fashion, all private devices can now talk to all public devices, and all public devices can talk to all private devices.

Because we have stated that private devices can only talk to devices with private addresses, some form of translation must take place. We show an example of this in Figure 2-17.

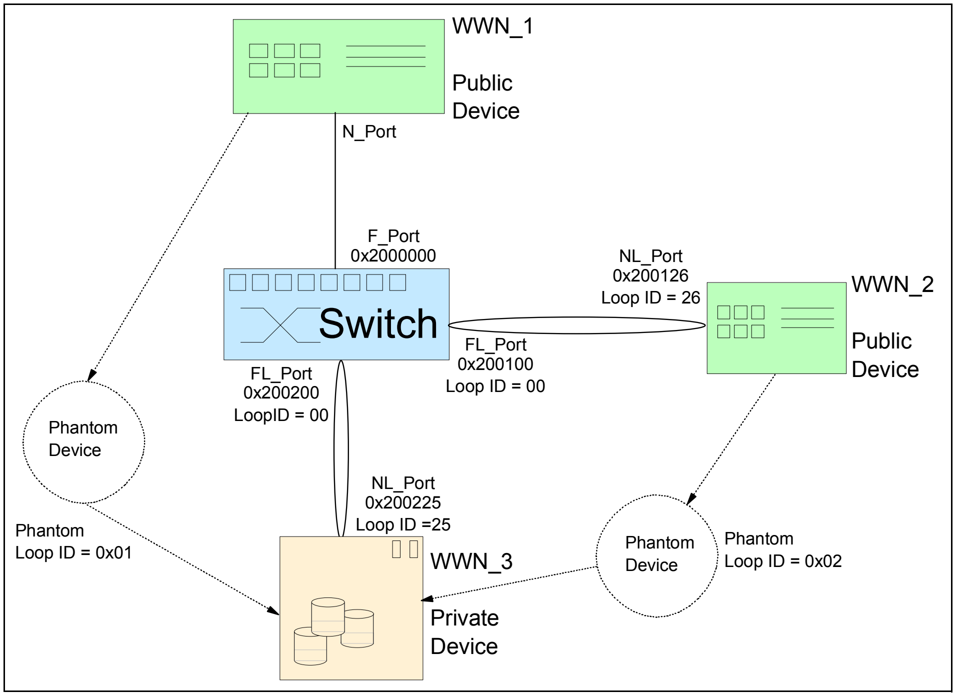


Figure 2-17 Arbitrated loop address translation

As you can see, we have three devices connected to the switch:

- Public device N_Port with WWN address WWN_1 on F_Port with the port address 0x200000
- Public device NL_Port with WWN address WWN_2 on FL_Port with the port address 0x200100. The device has AL_PA 0x26 on the loop which is attached on the FL_Port
- Private device NL_Port with WWN address WWN_3 on FL_Port with the port address 0x200200. The device has AL_PA 0x25 on the loop which is attached to the FL_Port

After all FLOGI and PLOGI functions are performed the SNS will have the entries shown in Table 2-4.

Table 2-4 Name server entries

24-bit port address	WWN	FL_Port address
0x200000	WWN_1	n/a
0x200126	WWN_2	0x200100
0x200225	WWN_3	0x200200

We now explain some possible scenarios.

Public N_Port device accesses private NL_Port device

The communication from device to device starts with PLOGI to establish a session. When a public N_Port device wants to perform a PLOGI to a private NL_Port device, the FL_Port on which this private device exists will assign a “phantom” private address to the public device. This phantom address is known only inside this loop, and the switch keeps track of the assignments.

In our example, when the WWN_1 device wants to talk to the WWN_3 device, the following, shown in Table 2-5, is created in the switch.

Table 2-5 Phantom addresses

Switch port address	Phantom loop port ID
0x200000	0x01
0x200126	0x02

When the WWN_1 device enters into the loop it represents itself with AL_PA ID 0x01 (its phantom address). All private devices on that loop use this ID to talk to that public device. The switch itself acts as a proxy, and translates addresses in both directions. Usually the number of phantom addresses is limited, and this number of phantom addresses decreases the number of devices allowed in the arbitrated loop. For example, if the number of phantom addresses is 32, this limits the number of physical devices in the loop to 126 - 32 = 94.

Public N_Port device accesses public NL_Port device

If an N_Port public device wants to access an NL_Port public device, it simply performs a PLOGI with the whole 24-bit address.

Private NL_Port device accesses public N_Port or NL_Port device

When a private device needs to access a remote public device, it uses the public device’s phantom address. When the FL_Port detects the use of a phantom AL_PA ID, it translates that to a switch port ID using its translation table similar to that shown in Table 2-5.

Translative mode

As explained above, private devices can cooperate in the fabric using translative mode. However, if you have a private host (server), this is not possible. To solve this, switch vendors, including IBM, support a translative feature. This feature, often referred to and defined in the FC standards as TL_Mode, allows the whole switch or director, or just a set of ports, to operate as an arbitrated loop. In this mode, devices connected to the switch do not perform a fabric login, and the switch itself will emulate the loop for those devices. All public devices can still see all private devices in translative mode. This is described comprehensively in “Private devices on NL_Ports” on page 45.

Switching mechanism and performance

In a switched fabric, a “cut-through” switching mechanism is used. This is not unique to switched fabrics and it is also used in Ethernet switches. The function is to speed packet routing from port to port.

When a frame enters the switch, cut-through logic examines only the link level destination ID of the frame. Based on the destination ID, a routing decision is made, and the frame is switched to the appropriate port by internal routing logic contained in the switch. It is this cut-through which increases performance by reducing the time required to make a routing decision. The reason for this is that the destination ID resides in the first four bytes of the frame header, and this allows the cut-through to be accomplished quickly. A routing decision can be made at the instant the frame enters the switch, without interpretation of anything other than the four bytes.

Switch frame buffering

An important criterion in selecting a switch is the number of frames that can be buffered on the port. During periods of high activity and frame movement, the switch may not be able to transmit a frame to its intended destination. This is true if two ports are sending data to the same destination. Given this situation, but depending on the class of service, the switch may sacrifice the frames it is not able to process. Not only does frame buffering reduce this likelihood, it also enhances performance.

Domain number routing decision

Another great performance improvement can be realized in the way in which the 24-bit port address is built. Because the address is divided into domain, area, and port, it is possible to make the routing decision on a single byte. As one example of this, if the domain number of the destination address indicates that the frame is intended for a different switch, the routing process can forward the frame to the appropriate interconnection without the need to process the entire 24-bit address and the associated overhead.

Data path in switched fabric

A complex switched fabric can be created by interconnecting Fibre Channel switches. Switch-to-switch connections are performed by E_Port connections. This mean that if you want to interconnect switches, they need to support E_Ports. Switches may also support multiple E_Port connections to expand the bandwidth.

In such a configuration with interconnected switches, known as a meshed topology, multiple paths from one N_Port to another can exist.

An example of a meshed topology is shown in Figure 2-18.

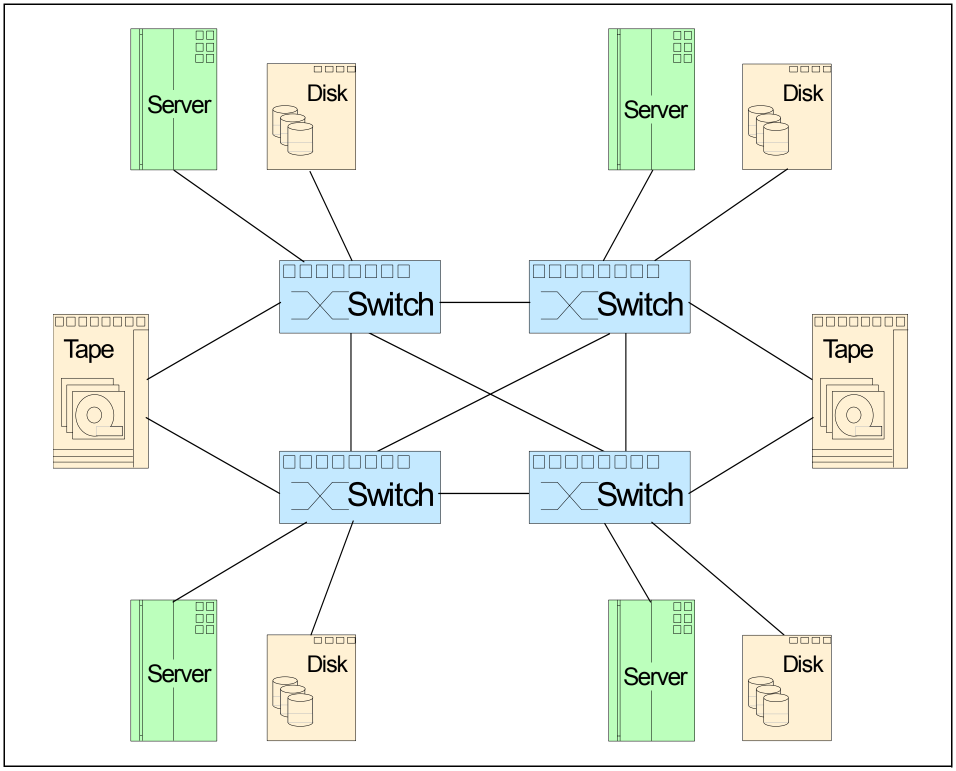


Figure 2-18 Meshed topology switched fabric

Spanning tree

In case of failure, it is important to consider having an alternative path between source and destination available. This will allow the data still to reach its destination. However, having different paths available could lead to the delivery of frames being out of the order of transmission, due to a frame taking a different path and arriving earlier than one of its predecessors.

A solution, which can be incorporated into the meshed fabric, is called a spanning tree and is an IEEE 802.1 standard. This means that switches keep to certain paths, as the spanning tree protocol will block certain paths to produce a simply connected active topology. Then the shortest path in terms of hops is used to deliver the frames and, most importantly, only one path is active at a time. This means that all associated frames go over the same path to the destination. The paths that are blocked can be held in reserve and used only if, for example, a primary path fails. The fact that one path is active at a time means that in the case of a meshed fabric, all frames will arrive in the expected order.

Path selection

For path selection, link state protocols are popular and extremely effective in today's networks. Examples of link state protocol are OSPF for IP and PNNI for ATM.

The most commonly used path selection protocol is Fabric Shortest Path First (FSPF). This type of path selection is usually performed at boot time, and no configuration is needed. All paths are established at start time, and only if the inter switch link (ISL) is broken or added will reconfiguration take place.

If multiple paths are available and if the primary path goes down, the traffic will be rerouted to another path. If the route fails, this can lead to congestion of frames, and any new frames delivered over the new path could potentially arrive at the destination first. This will cause an out-of-sequence delivery.

One possible solution for this is to prevent the activation of the new route for a while (this can be configured from milliseconds to a few seconds), so the congested frames are either delivered or rejected. Obviously, this can slow down the routing, so it should only be used when the devices connected to the fabric are not in a position to, or cannot tolerate, occasional out-of-sequence delivery. For instance, video can tolerate an out-of-sequence delivery, but financial and commercial data cannot.

But today, Fibre Channel devices are much more sophisticated, and this is a feature that is not normally required. FSPF allows a fabric to still benefit from load balancing the delivery of frames by using multiple paths.

We discuss FSPF in greater depth in “Fabric shortest path first” on page 91.

Route definition

Routes are usually dynamically defined. Static routes can also be defined. In the event that a static route fails, a dynamic route will take over. Once the static route becomes available again, frames will return to utilizing that route.

If dynamic paths are used, FSPF path selection is used. This guarantees that only the shortest and fastest paths will be used for delivering the frames.

We show an example of FSPF in Figure 2-19.

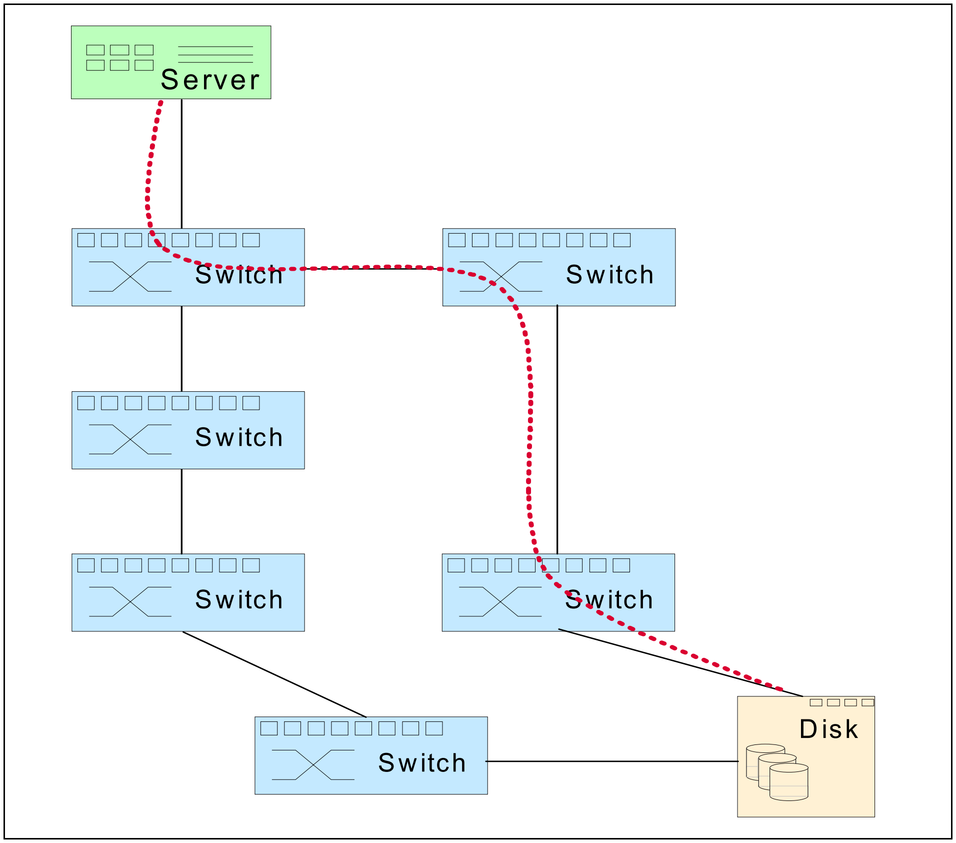


Figure 2-19 Fabric shortest path first

Adding new devices

Switched fabrics, by their very nature, are dynamic environments. They can handle topology changes as new devices are attached, or previously active devices are removed or taken offline. For these reasons it is important that notification of these types of events can be provided to participants (nodes) in the switched fabric.

Notification is provided by two functions:

- State Change Notification: SCN
- Registered State Change Notification: RSCN

These two functions are not obligatory, so each N_Port or NL_Port must register its interest in being notified of any topology changes, or if another device alters its state.

The original SCN service allowed an N_Port to send a notification change directly to another N_Port. This is not necessarily an optimum solution, as no other participants on the fabric will know about this change. RSCN offers a solution to this and will inform all registered devices about the change.

Perhaps the most important change that you would want to be notified about, is when an existing device goes offline. This information is very meaningful for participants that communicate with that device. For example, a server in the fabric environment would want to know if their resources are powered off or removed, or when new resources became available for its use.

Changed notification provides the same functionality for the switched fabric as loop initialization provides for arbitrated loop.

2.4.5 WWN and WWPN

Each device in the SAN is identified by a unique world wide name (WWN). The WWN contains a vendor identifier field, which is defined and maintained by the IEEE, and a vendor specific information field.

For further information, visit the Web site:

http://standards.ieee.org/

Currently, there are two formats of the WWN as defined by the IEEE. The original format contains either a hex 10 or hex 20 in the first two bytes of the address. This is then followed by the vendor specific information.

The new addressing scheme starts with a hex 5 or 6 in the first half-byte followed by the vendor identifier in the next 3 bytes. The vendor specific information is then contained in the following fields.

Both the old and new WWN formats are shown in Figure 2-20.

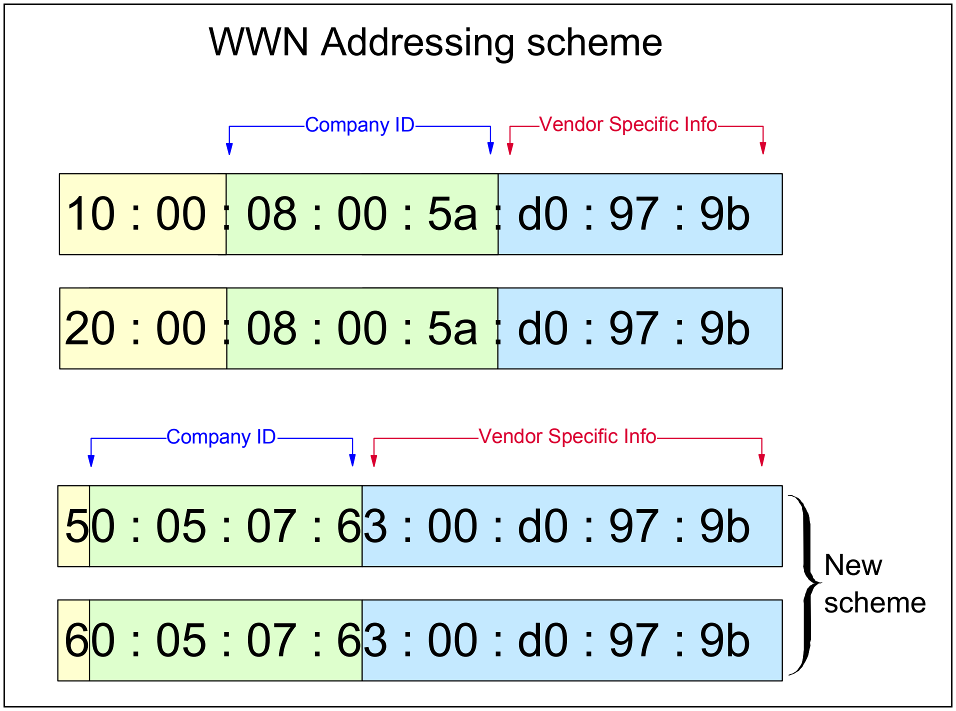

WWN Addressing scheme
Company ID
Vendor Specific Info
10 : 00 : 08 : 00 : 5a : d0 : 97 : 9b
20 : 00 : 08 : 00 : 5a : d0 : 97 : 9b
Company ID
Vendor Specific Info
50 : 05 : 07 : 63 : 00 : d0 : 97 : 9b
60 : 05 : 07 : 63 : 00 : d0 : 97 : 9b
New scheme

Figure 2-20 World Wide Name addressing scheme

The complete list of vendor identifiers as maintained by the IEEE is available at:

`http://standards.ieee.org/regauth/oui/oui.txt`

Table 2-6 lists a few of these vendor identifiers.

Table 2-6 WWN company identifiers

WWN (hex)	Company
00-50-76	IBM Corporation
00-60-69	Brocade Communications
08-00-88	McDATA Corporation
00-60-DF	CNT Technologies Corporation

Some devices may have multiple Fibre Channel adapters, like an ESS, for example. In this case the device also has an identifier for each of its Fibre Channel adapters. This identifier is called the world wide port name (WWPN). This way it is possible to uniquely identify all Fibre Channel adapters and paths within a device.

This is illustrated in Figure 2-21.

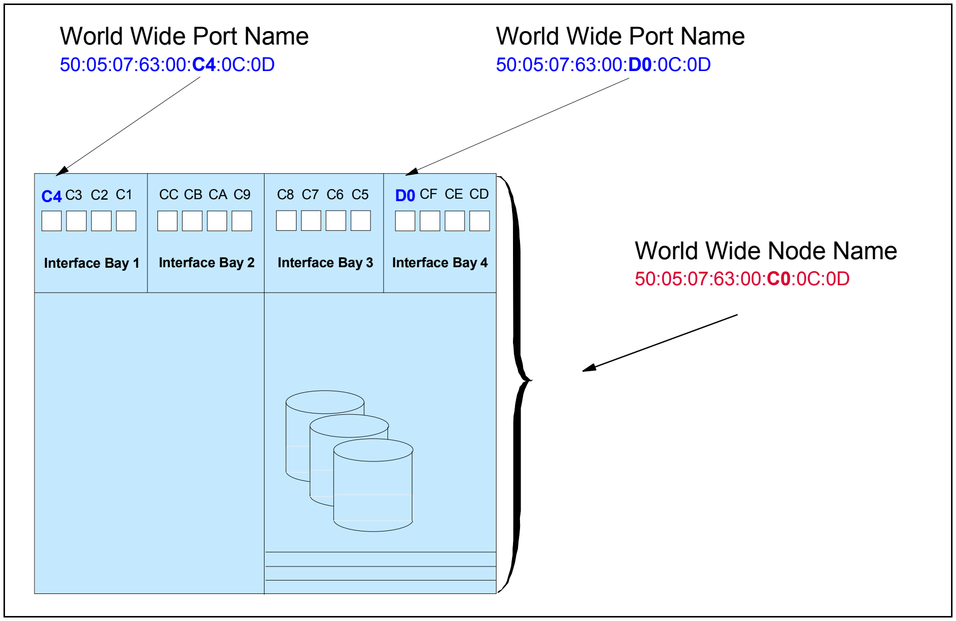
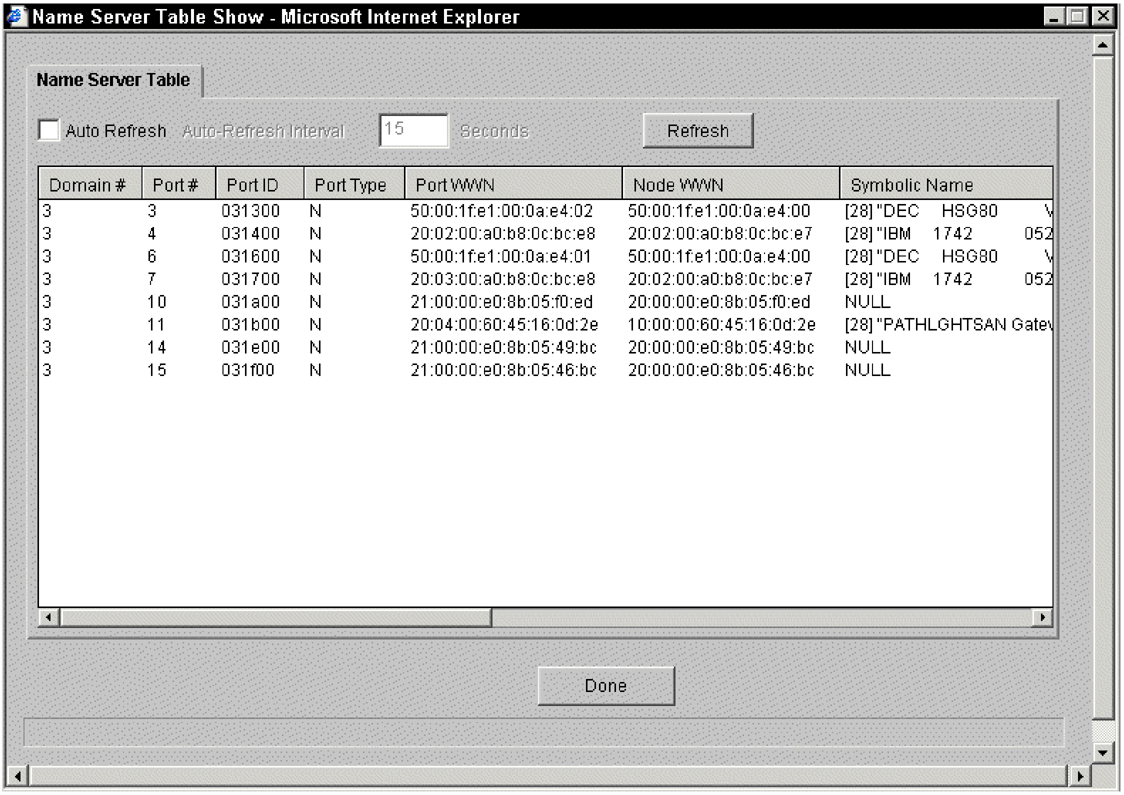


Figure 2-21 WWN and WWPN

This diagram shows how each of the ESS's Fibre Channel adapters has a unique WWPN. In the case of the ESS, the vendor specific information field is used to identify each Fibre Channel adapter according to which bay and slot position it is installed in within the ESS.

Shown in Figure 2-22 is a screen capture of the name server table for a test SAN in the ITSO lab. This shows that the two devices (DEC HSG80 and IBM 1742) both have multiple HBAs. The name server table shows the WWN for each device as being the same, but the WWPN is different for each HBA within these devices.



Domain #	Port #	Port ID	Port Type	Port WWN	Node WWN	Symbolic Name
3	3	031300	N	50:00:1f:e1:00:0a:e4:02	50:00:1f:e1:00:0a:e4:00	[28] "DEC HSG80 V
3	4	031400	N	20:02:00:a0:b8:0c:bc:e8	20:02:00:a0:b8:0c:bc:e7	[28] "IBM 1742 052
3	6	031600	N	50:00:1f:e1:00:0a:e4:01	50:00:1f:e1:00:0a:e4:00	[28] "DEC HSG80 V
3	7	031700	N	20:03:00:a0:b8:0c:bc:e8	20:02:00:a0:b8:0c:bc:e7	[28] "IBM 1742 052
3	10	031a00	N	21:00:00:e0:8b:05:f0:ed	20:00:00:e0:8b:05:f0:ed	NULL
3	11	031b00	N	20:04:00:60:45:16:0d:2e	10:00:00:60:45:16:0d:2e	[28] "PATHLGHTSAN Gatev
3	14	031e00	N	21:00:00:e0:8b:05:49:bc	20:00:00:e0:8b:05:49:bc	NULL
3	15	031f00	N	21:00:00:e0:8b:05:46:bc	20:00:00:e0:8b:05:46:bc	NULL

Figure 2-22 WWN and WWPN entries in a name server table

2.4.6 Zoning

Zoning allows for finer segmentation of the switched fabric. Zoning can be used to instigate a barrier between different environments. Only members of the same zone can communicate within that zone, and all other attempts from outside the zone are rejected.

For example, it may be desirable to separate a Windows environment from a UNIX environment. This is very useful because of the manner in which Windows attempts to claim all available storage for itself. Because not all storage devices are capable of protecting their resources from any host searching for available resources, it makes sound business sense to protect the environment.

Looking at zoning in this way, it could also be considered as a security feature and not just for separating environments. Zoning could also be used for test and maintenance purposes. For example, not many enterprises will mix their test and maintenance environments with their production environment. Within a fabric, you could easily separate your test environment from your production bandwidth allocation on the same fabric using zoning.

In fact, it is of historical note that zoning was developed to prevent some operating systems from writing their signature on all devices that they saw. This would mean that unsuspecting operating systems that were less parochial in nature had the potential to lose access to their disks.

We show an example of zoning in Figure 2-23 where we have separated AIX® from NT and created Zone 1 and Zone 2. This diagram also shows how a device can be in more than one zone.

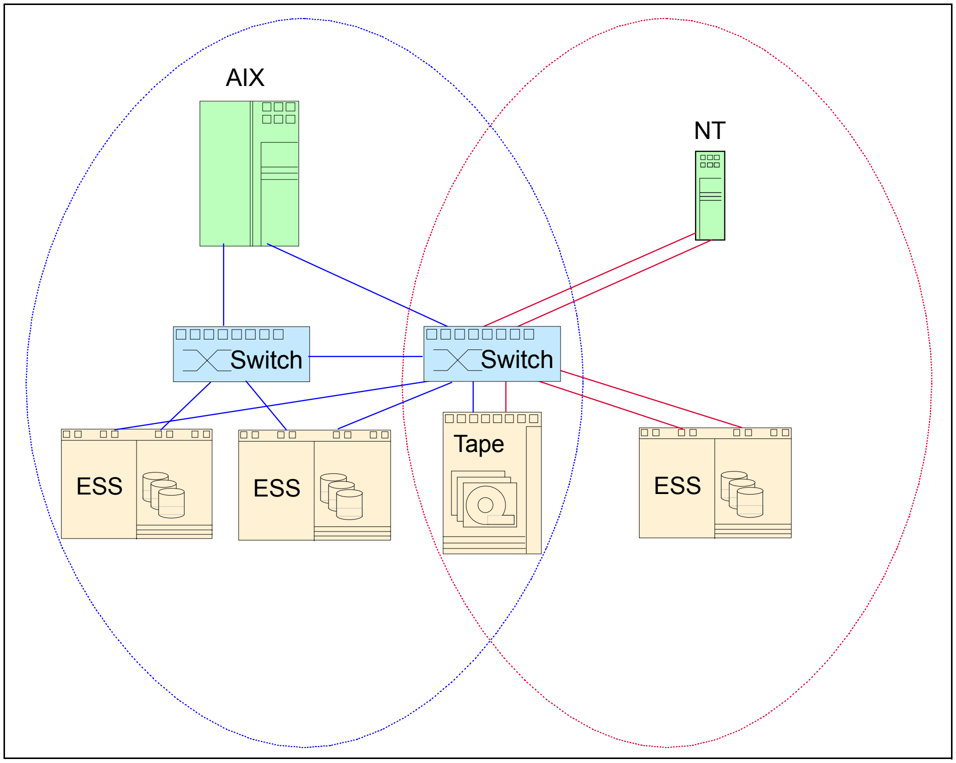


Figure 2-23 Zoning

Zoning also introduces the flexibility to manage a switched fabric to meet different user groups objectives.

Implementing zoning

Zoning can be implemented in two ways:

- Hardware zoning
- Software zoning

Hardware or port zoning

Hardware zoning is based on the physical fabric port number. The members of a zone are physical ports on the fabric switch. It can be implemented in the following configurations:

- One-to-one
- One-to-many
- Many-to-many

A single port can also belong to multiple zones. We show an example of hardware zoning in Figure 2-24.

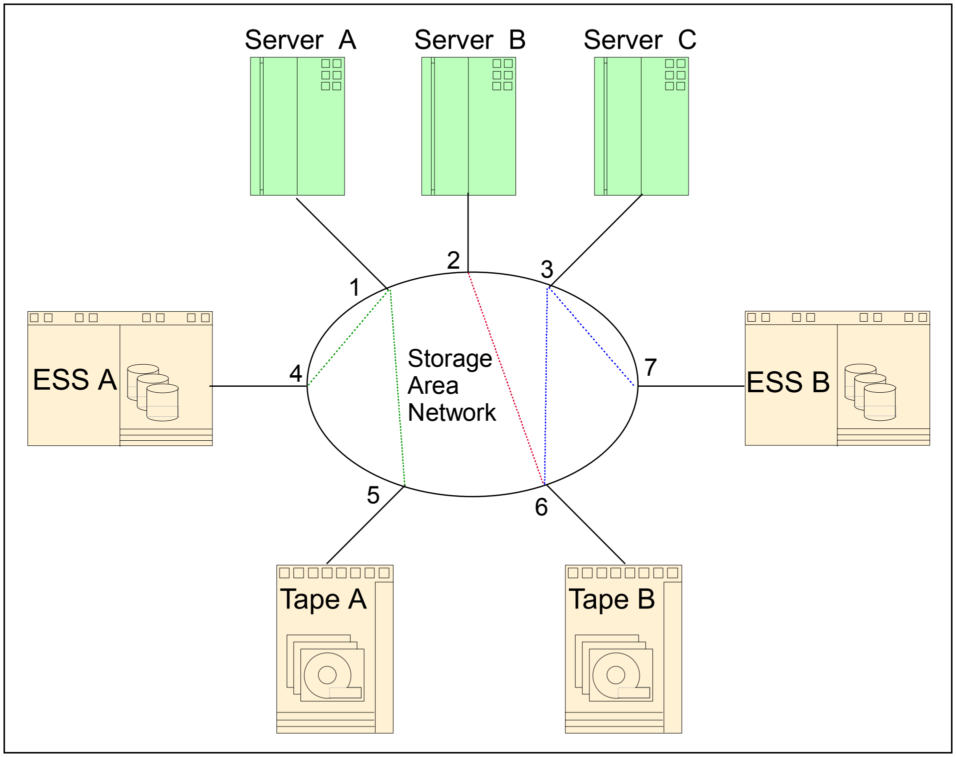


Figure 2-24 Zoning based on the switch port-number

In this example, port-based zoning is used to restrict Server A to only see storage devices that are zoned to port 1, that is, ports 4 and 5.

Server B is also zoned so that it can only see from port 2 through to port 6.

Server C is zoned so that it can see both ports 6 and 7 even though port 6 is also a member of another zone.

One of the disadvantages of port-based zoning is that devices have to be connected to a specific port, and the whole zoning configuration could become unusable if the device is connected to a different port.

For example, if the device attached to port 4 was removed and re-cabled into port 7, Server C would be able to see through to ESS A. That could cause an issue if that server is not allowed to see this device.

This example could also occur if port 4 failed requiring ESS A to be re-cabled into a new port (port 8 for example). Any zone containing reference to port 4 would need to be replaced with the new port number (port 8 in this case). This would involve having to manually update the zoning information and applying the change to the fabric.

The advantage of port-based zoning is that it can be implemented into a routing engine by filtering. As a result, this kind of zoning has a very low impact on the performance of the routing process.

In cases where the device connections are not permanent the use of WWN zoning is recommended.

Software or WWN zoning

Software zoning is implemented within the name server running inside the fabric switch. When using software zoning the members of the zone can be defined by:

- Node WWN
- Port WWN

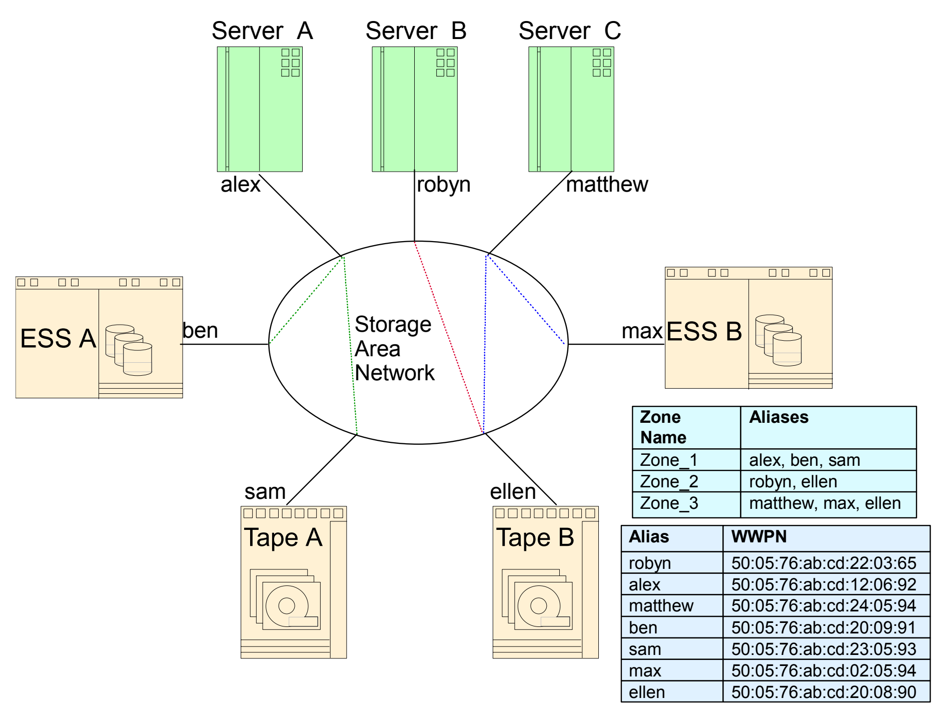
Usually zoning software also allows you to create symbolic names or aliases for the zone members and for the zones themselves. Dealing with the symbolic name or aliases for a device is often easier than trying to use the WWN address, which, for example, is in the format of 20:0a:00:ab:cd:12:23:34.

The number of members possible in a zone is limited only by the amount of memory in the fabric switch. A member can belong to multiple zones. You can define multiple configurations or sets of zones for the fabric, but only one configuration or set can be active or enabled at any time. You can activate another zone set or configuration any time you want, without the need to power down the switch.

With software zoning there is no need to worry about the physical connections to the switch. If you use WWNs for the zone members, even when a device is connected to another physical port, it will still remain in the same zoning definition, because the device's WWN remains the same. The zone follows the WWN.

Shown in Figure 2-25 is an example of WWN based zoning. In this example symbolic names are defined for each WWN in the SAN to implement the same zoning requirements, as shown in the previous example for port zoning:

- **Zone_1** contains the aliases **alex**, **ben**, and **sam**, and is restricted to only these devices.
- **Zone_2** contains the aliases **robyn** and **ellen**, and is restricted to only these devices.
- **Zone_3** contains the aliases **matthew**, **max**, and **ellen**, and is restricted to only these devices.



Zone Name	Aliases
Zone_1	alex, ben, sam
Zone_2	robyn, ellen
Zone_3	matthew, max, ellen

Alias	WWPN
robyn	50:05:76:ab:cd:22:03:65
alex	50:05:76:ab:cd:12:06:92
matthew	50:05:76:ab:cd:24:05:94
ben	50:05:76:ab:cd:20:09:91
sam	50:05:76:ab:cd:23:05:93
max	50:05:76:ab:cd:02:05:94
ellen	50:05:76:ab:cd:20:08:90

Figure 2-25 Zoning based on the devices WWN

There can be a potential security leak with software zoning. When a specific host logs into the fabric and asks for available storage devices, the name server will query the software zoning table to see which storage devices are allowable for that host. The host will only see the storage devices defined in the software zoning table. But the host can also make a direct connection to the storage device, while doing device discovery, without asking the name server for the information it has.

Additionally, any device that does any form of probing for WWNs may be able to discover devices and talk to them. A simple analogy might be that of an unlisted telephone number where, although the telephone number is not publicly available, there is nothing to stop a person from dialing that number whether by design or accident. The same holds true for WWNs, and there are devices that will randomly probe for WWNs to see if they can start a conversation with them. These are known as “bad citizens”.

A number of switch vendors offer hardware enforced WWN zoning, which can prevent this security exposure.

Note: For maximum security, hardware zoning is recommended. But as the standards are evolving and the industry is following them, it is likely that in the future, software zoning will probably be the preferred solution.

LUN masking

Another approach to securing storage devices from hosts wishing to take over already assigned resources is logical unit number (LUN) masking. Every storage device offers its resources to the hosts by means of LUNs.

For example, each partition in the storage server has its own LUN. If the host (server) wants to access the storage, it needs to request access to the LUN in the storage device. The purpose of LUN masking is to control access to the LUNs. The storage device itself accepts or rejects access requests from different hosts.

The user defines which hosts can access which LUN by means of the storage device control program. Whenever the host accesses a particular LUN, the storage device will check its access list for that LUN, and it will allow or disallow access to the LUN.

2.4.7 Expanding the fabric

As the demand for access to the storage grows, a switched fabric can be expanded to service these needs. Not all storage requirements can be satisfied with fabrics alone. For some applications, the 200 MB/s per port and advanced services are overkill, and they amount to wasted bandwidth and unnecessary cost. When you design a storage network, you need to consider the application's needs and not just rush to implement the latest technology available. SANs are often combinations of switched fabric and arbitrated loops.

Cascading

Expanding the fabric is called switch cascading. Cascading is basically interconnecting Fibre Channel switches and/or directors. The cascading of switches provides the following benefits to a SAN environment:

- The fabric can be seamlessly extended. Additional switches can be added to the fabric, without powering down existing fabric.
- You can easily increase the distance between various SAN participants.
- By adding more switches to the fabric, you increase connectivity by providing more available ports.
- Cascading provides high resilience in the fabric.
- With inter-switch links (ISLs), you can increase the bandwidth. The frames between the switches are delivered over all available data paths. So the more ISLs you create, the faster the frame delivery will be, but careful consideration must be employed to ensure that a bottleneck is not introduced.
- When the fabric grows, the name server is fully distributed across all the switches in fabric.
- With cascading, you also provide greater fault tolerance within the fabric.

Hops

As we stated in "Name and addressing" on page 42, the maximum number of switches allowed in the fabric is 239. The other limitation is that only seven hops are allowed between any source and destination using IBM 2109 switches. However, this is likely to change between vendors and over time.

We show a sample configuration that illustrates this in Figure 2-26, with “Hoppy”, the hop count kangaroo.

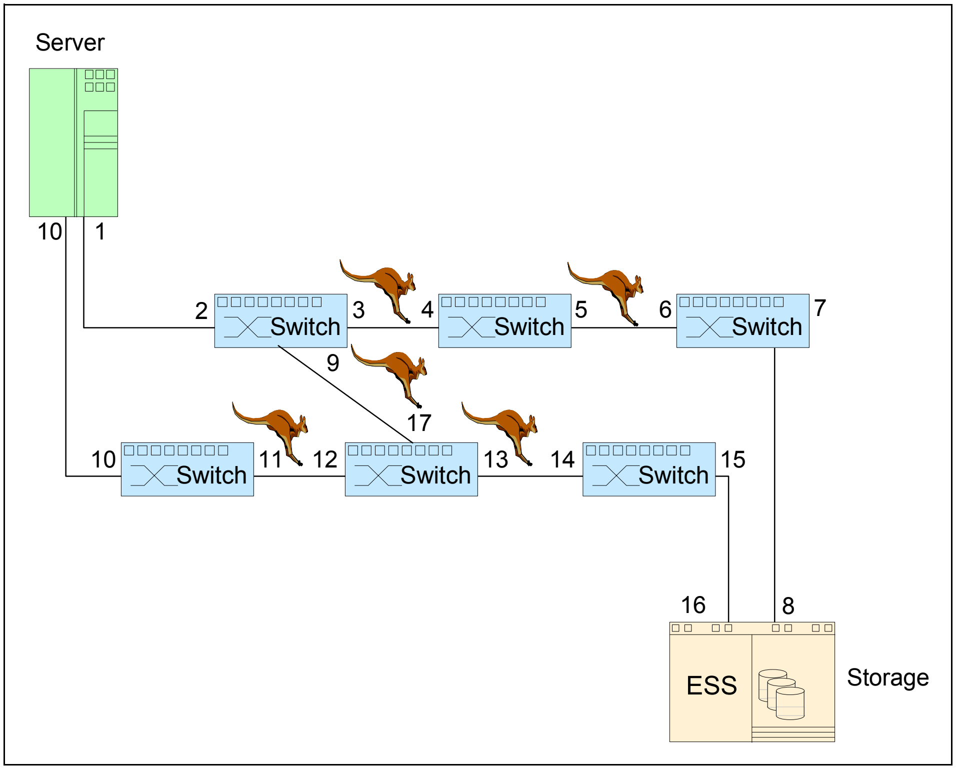


Figure 2-26 Cascading in a switched fabric

The hop count limit is set by the fabric operating system and is used to derive a frame holdtime value for each switch. This holdtime value is the maximum amount of time that a frame can be held in a switch before it is dropped (Class 3) or the fabric is busy (F_BSY, Class 2) is returned. A frame would be held if its destination port is not available. The holdtime is derived from a formula using the error detect time-out value (E_D_TOV) and the resource allocation time-out value (R_A_TOV).

The value of seven hops is not “hard-coded”, and if manipulation of E_D_TOV or R_A_TOV were to take place, the reasonable limit of seven hops could be exceeded. However, be aware that any hop suggestion was not a limit that was arrived at without careful consideration of a number of factors. In the future, the number of hops is likely to increase.

2.5 SAN software management standards

Traditionally, storage management has been the responsibility of the host server to which the storage resources are attached. With storage networks the focus has shifted away from individual server platforms, making storage management independent of the operating system, and offering the potential for greater flexibility by managing shared resources across the enterprise SAN infrastructure. Software is needed to configure, control, and monitor the SAN and all of its components in a consistent manner. Without good software tools, SANs cannot be implemented effectively.

The management challenges faced by SANs are very similar to those previously encountered by LANs and WANs. Single vendor proprietary management solutions will not satisfy customer requirements in a multi-vendor heterogeneous environment. The pressure is on the vendors to establish common methods and techniques. For instance, the need for platform independence for management applications, to enable them to port between a variety of server platforms, has encouraged the use of Java™.

The Storage Network Management Working Group (SNMWG) of SNIA is working to define and support open standards needed to address the increased management requirements imposed by SAN topologies. Reliable transport of the data, as well as management of the data and resources (such as file access, backup, and volume management) are key to stable operation. SAN management requires a hierarchy of functions, from management of individual devices and components, to the network fabric, storage resources, data, and applications. This is shown in Figure 2-27.

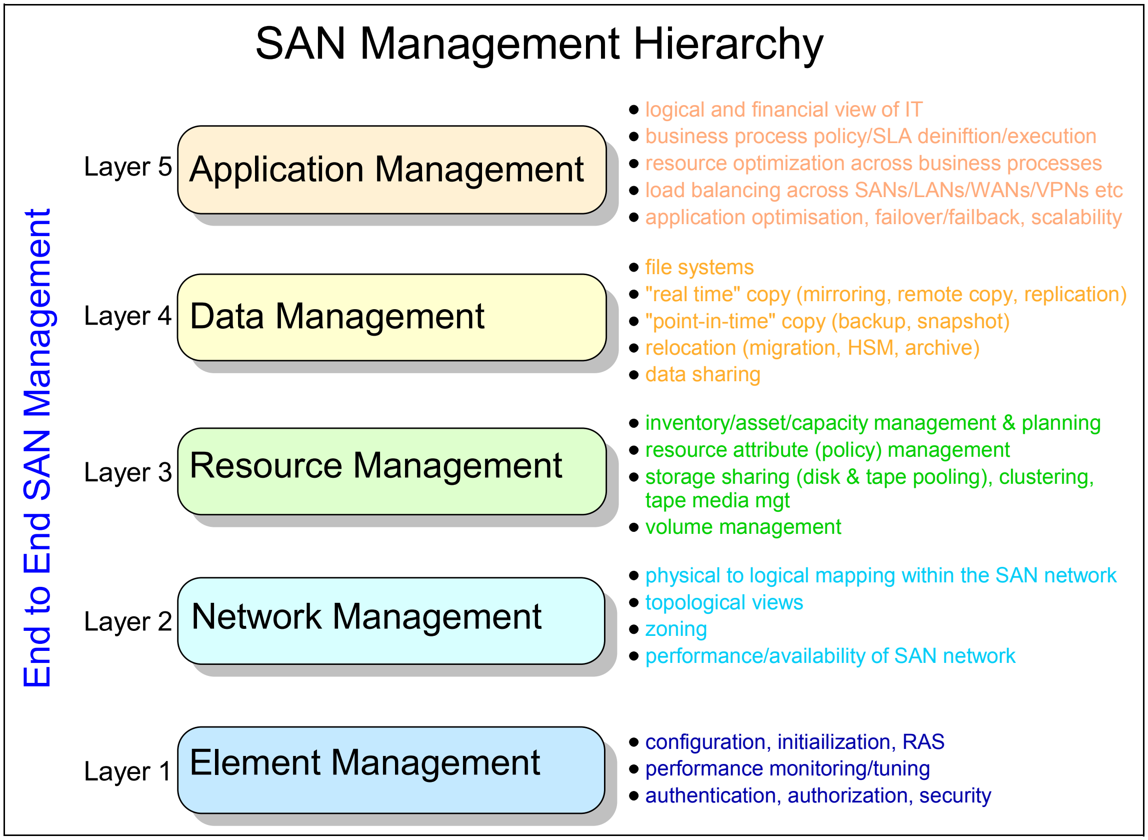

SAN Management Hierarchy
End to End SAN Management
Layer 5
Application Management
• logical and financial view of IT
• business process policy/SLA deiniftion/execution
• resource optimization across business processes
• load balancing across SANs/LANs/WANs/VPNs etc
• application optimisation, failover/failback, scalability
Layer 4
Data Management
• file systems
• "real time" copy (mirroring, remote copy, replication)
• "point-in-time" copy (backup, snapshot)
• relocation (migration, HSM, archive)
• data sharing
Layer 3
Resource Management
• inventory/asset/capacity management & planning
• resource attribute (policy) management
• storage sharing (disk & tape pooling), clustering, tape media mgt
• volume management
Layer 2
Network Management
• physical to logical mapping within the SAN network
• topological views
• zoning
• performance/availability of SAN network
Layer 1
Element Management
• configuration, initiailization, RAS
• performance monitoring/tuning
• authentication, authorization, security

Figure 2-27 SAN management hierarchy

These can be implemented separately, or potentially as a fully integrated solution to present a single interface to manage all SAN resources.

2.5.1 Application management

Application management is concerned with the availability, performance, and recoverability of the applications that run your business. Failures in individual components are of little consequence if the application is unaffected. By the same measure, a fully functional infrastructure is of little use if it is configured incorrectly or if the data placement makes the application unusable. Enterprise application and systems management is at the top of the hierarchy and provides a comprehensive, organization-wide view of all network resources (fabric, storage, servers, applications).

A flow of information regarding configuration, status, statistics, capacity utilization, performance, and so on, must be directed up the hierarchy from lower levels. A number of industry initiatives are directed at standardizing the storage specific information flow using a Common Information Model (CIM) or application programming interfaces (API), such as those proposed by the Jiro initiative, sponsored by Sun Microsystems, and others by SNIA and SNMWG.

Figure 2-28 illustrates a common interface model for heterogeneous, multi-vendor SAN management.

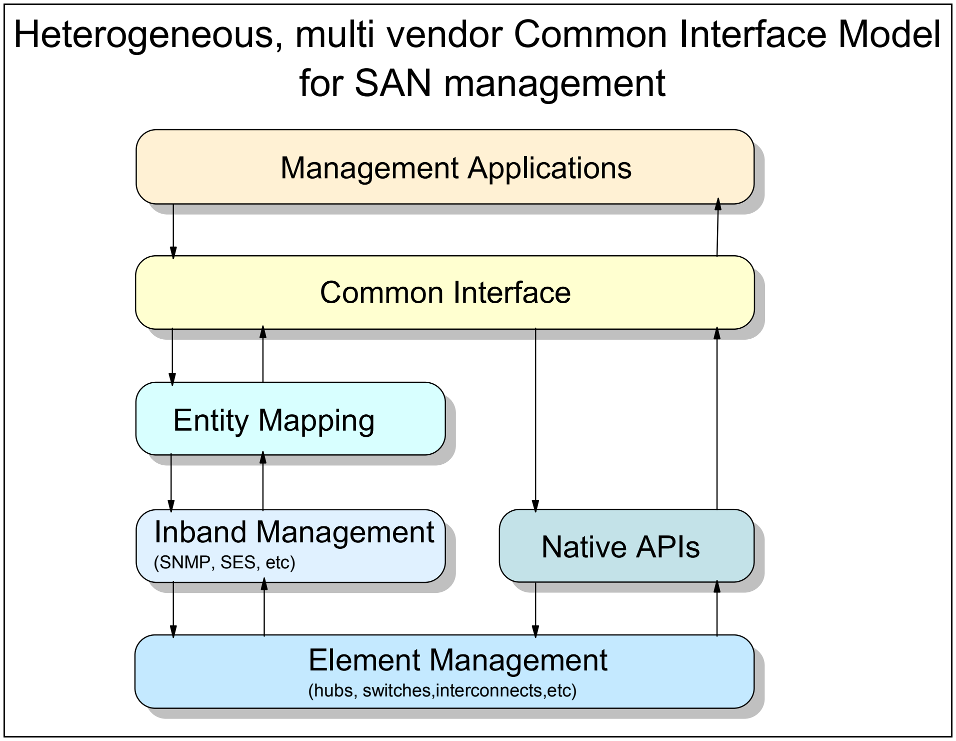


Figure 2-28 Common Interface Model for SAN management

2.5.2 Data management

More than at any other time in history, digital data is fueling business. Data management is concerned with Quality-of-Service (QoS) issues surrounding this data, such as:

- Ensuring data availability and accessibility for applications
- Ensuring proper performance of data for applications
- Ensuring recoverability of data

Data management is carried out on mobile and remote storage, centralized host attached storage, network attached storage (NAS), and SAN attached storage (SAS). It incorporates backup and recovery, archive and recall, and disaster protection.

2.5.3 Resource management

Resource management is concerned with the efficient utilization and consolidated, automated management of existing storage and fabric resources, as well as automating corrective actions where necessary. This requires the ability to manage all distributed storage resources, ideally through a single management console, to provide a single view of enterprise resources.

Without such a tool, storage administration is limited to individual servers. Typical enterprises today may have hundreds, or even thousands, of servers and storage subsystems. This makes impractical the manual consolidation of resource administration information, such as enterprise-wide disk utilization, or regarding the location of storage subsystems. SAN resource management addresses tasks such as:

- Pooling of disk resources
- Space management
- Pooling and sharing of removable media resources
- Implementation of “just-in-time” storage

2.5.4 Network management

Every e-business depends on existing LAN and WAN connections in order to function. Because of their importance, sophisticated network management software has evolved. Now SANs are allowing us to bring the same physical connectivity concepts to storage. And like LANs and WANs, SANs are vital to the operation of an e-business. Failures in the SAN can stop the operation of an enterprise.

SANs can be viewed as both physical and logical entities.

SAN physical view

The physical view identifies the installed SAN components, and allows the physical SAN topology to be understood. A SAN environment typically consists of four major classes of components:

- End-user computers and clients
- Servers
- Storage devices and subsystems
- Interconnect components

End-user platforms and server systems are usually connected to traditional LAN and WAN networks. In addition, some end-user systems may be attached to the Fibre Channel network, and may access SAN storage devices directly. Storage subsystems are connected using the Fibre Channel network to servers, end-user platforms, and to each other. The Fibre Channel network is made up of various interconnect components, such as switches, hubs, and bridges (Figure 2-29).

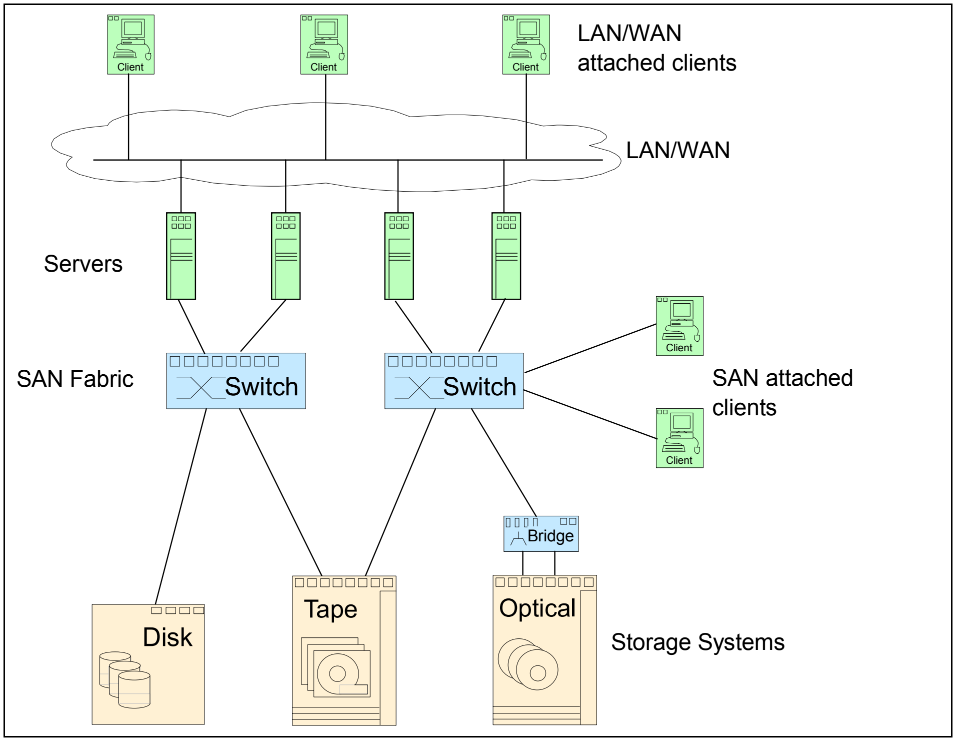


Figure 2-29 Typical SAN environment

SAN logical view

The logical view identifies and understands the relationships between SAN entities. These relationships are not necessarily constrained by physical connectivity, and they play a fundamental role in the management of SANs. For instance, a server and some storage devices may be classified as a logical entity. A logical entity group forms a private virtual network, or zone, within the SAN environment with a specific set of connected members. Communication within each zone is restricted to its members.

Network management is concerned with the efficient management of the Fibre Channel SAN — especially in physical connectivity mapping, fabric zoning, performance monitoring, error monitoring, and predictive capacity planning.

2.5.5 Element management

The elements that make up the SAN infrastructure include intelligent disk subsystems, intelligent removable media subsystems, Fibre Channel switches, hubs and bridges, meta-data controllers, and out-board storage management controllers. The vendors of these components provide proprietary software tools to manage their individual elements, usually comprising software, firmware, and hardware elements, such as those shown in Figure 2-30.

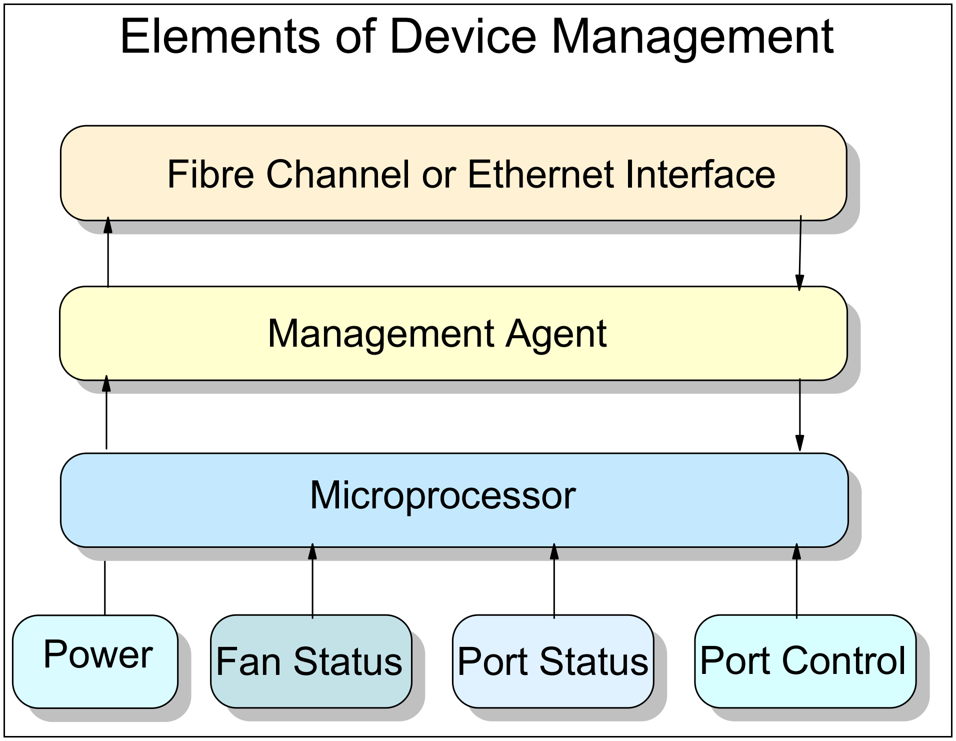


Figure 2-30 Device management elements

For instance, a management tool for a hub will provide information regarding its own configuration, status, and ports, but will not support other fabric components such as other hubs, switches, HBAs, and so on. Vendors that sell more than one element commonly provide a software package that consolidates the management and configuration of all of their elements. Modern enterprises, however, often purchase storage hardware from a number of different vendors.

Fabric monitoring and management is an area where a great deal of standards work is being focused. Two management techniques are in use — in-band and out-of-band management.

In-band management

Device communications to the network management facility is most commonly done directly across the Fibre Channel transport, using a protocol called SCSI Enclosure Services (SES). This is known as in-band management. It is simple to implement, requires no LAN connections, and has inherent advantages, such as the ability for a switch to initiate a SAN topology map by means of SES queries to other fabric components. However, in the event of a failure of the Fibre Channel transport itself, the management information cannot be transmitted. Therefore, access to devices is lost, as is the ability to detect, isolate, and recover from network problems. This problem can be minimized by provision of redundant paths between devices in the fabric.

- **In-band developments:** In-band management is evolving rapidly. Proposals exist for low level interfaces such as Return Node Identification (RNID) and Return Topology Identification (RTIN) to gather individual device and connection information, and for a Management Server that derives topology information. In-band management also allows attribute inquiries on storage devices and configuration changes for all elements of the SAN. Since in-band management is performed over the SAN itself, administrators are not required to make additional TCP/IP connections.

Out-of-band management

Out-of-band management means that device management data are gathered over a TCP/IP connection such as Ethernet. Commands and queries can be sent using Simple Network Management Protocol (SNMP), Telnet (a text-only command line interface), or a Web browser Hyper Text Transfer Protocol (HTTP). Telnet and HTTP implementations are more suited to small networks.

Out-of-band management does not rely on the Fibre Channel network. Its main advantage is that management commands and messages can be sent even if a loop or fabric link fails. Integrated SAN management facilities are more easily implemented, especially by using SNMP. However, unlike in-band management, it cannot automatically provide SAN topology mapping.

- **Out-of-band developments:** Two primary SNMP MIBs are being implemented for SAN fabric elements that allow out-of-band monitoring. The ANSI Fibre Channel Fabric Element MIB provides significant operational and configuration information on individual devices. The emerging Fibre Channel Management MIB provides additional link table and switch zoning information that can be used to derive information about the physical and logical connections between individual devices. Even with these two MIBs, out-of-band monitoring is incomplete. Most storage devices and some fabric devices don’t support out-of-band monitoring. In addition, many administrators simply don’t attach their SAN elements to the TCP/IP network.

- **Simple Network Management Protocol (SNMP):** This protocol is widely supported by LAN/WAN routers, gateways, hubs and switches, and is the predominant protocol used for multi vendor networks. Device status information (vendor, machine serial number, port type and status, traffic, errors, and so on) can be provided to an enterprise SNMP manager. This usually runs on a UNIX or NT workstation attached to the network. A device can generate an alert by SNMP, in the event of an error condition. The device symbol, or icon, displayed on the SNMP manager console, can be made to turn red or yellow, and messages can be sent to the network operator.
- **Management Information Base (MIB):** A management information base (MIB) organizes the statistics provided. The MIB runs on the SNMP management workstation, and also on the managed device. A number of industry standard MIBs have been defined for the LAN/WAN environment. Special MIBs for SANs are being built by the SNIA. When these are defined and adopted, multi-vendor SANs can be managed by common commands and queries.

Element management is concerned with providing a framework to centralize and automate the management of heterogeneous elements and to align this management with application or business policy.

2.5.6 Storage Management Initiative

The Storage Networking Industry Association (SNIA) has launched the Storage Management Initiative (SMI) to enable a standard to be developed that would provide a highly-functional open interface for the management of storage networks.

The goal of SMI is to produce a design specification that is based on the Common Information Model (CIM) and Web Based Enterprise Management (WEBM) standards.

Bluefin is the code name for a SAN Management specification that was developed by a group consisting of 16 SNIA members as a foundation for unifying the storage management industry on a management interface standard.

The Bluefin technology was developed with technical contributions from IBM and employs the Common Information Model (CIM) and Web Based Enterprise Management (WEBM) technology to discover and manage resources in a multi-vendor SAN through common interfaces. When implemented in products, the Bluefin technology will improve the usefulness of storage management applications and provide management interoperability in heterogeneous SANs. Bluefin has been presented as a technology contribution to SNIA.

IBM will incorporate the Bluefin specification into the Storage Tank™ SAN-wide file system and storage virtualization engine to extend the concept of SAN interoperability beyond basic system identification and monitoring to more comprehensive and efficient management capabilities. The Bluefin technology will also be incorporated into Tivoli Storage management offerings in the near future.

IBM's current and future storage software products will support interoperability in heterogeneous SANs by rapidly integrating and implementing Bluefin and other evolving standards for management of storage systems which are based on CIM.

An example of the Bluefin technology is the recent announcement between IBM and HP to cross license storage Application Programming Interfaces (API) to simplify storage management of both companies storage devices.

The cross licensing agreement will enable IBM software to use APIs to manage the HP Storage Works EMA (HSG80) and EVA (HSV110) arrays as well as the HP Storage Works MA8000 products. The APIs will also enable HP to manage the IBM Enterprise Storage Server through HP OpenView.

2.5.7 InfiniBand

This is a serial technology that can be implemented across either optical fiber or copper cabling. The parallel bus architecture has an inherent latency as it needs to wait for all the bits sent across a parallel link to arrive before it can send more data which slows a system down. InfiniBand is based around a serial link which reduces the number of pins and electrical interconnects that are required thereby reducing manufacturing costs and improving the reliability.

The InfiniBand Architecture is designed around a point-to-point, switched I/O fabric in which the devices are interconnected by cascaded switches. InfiniBand supports a range of applications and can be used to provide the backplane interconnect for a single host, or to building a complex system are network consisting of multiple independent and clustered hosts and I/O components.

An InfiniBand switch fabric looks quite similar to current Fibre Channel SANs. In this architecture, InfiniBand nodes (storage devices and servers) interconnect with one another over the InfiniBand I/O fabric.

For more information on the InfiniBand architecture, visit:

http://www.infinibandta.org/ibta/

2.6 Fabric management methods

The SAN fabric can be managed using several remote and local access methods. Each vendor will decide on the most appropriate methods to employ on their particular product. Not all vendors are the same and from a management point of view it makes sense to investigate the possibilities before any investment is made.

2.6.1 Common methods

There are several access methods for managing a switch or director. This is summarized in Table 2-7.

Switches can be accessed simultaneously from different connections. If this happens, changes from one connection may not be updated to the other, and some may be lost. Make sure when connecting with simultaneous multiple connections, that you do not overwrite the work of another connection.

Table 2-7 Comparison of management access methods

Management method	Description	Local	In-band (Fibre Channel)	Out-of-band (Ethernet)
Serial Port	CLI locally from serial port on the switch	Yes	No	No
Telnet	CLI remotely via Telnet	No	Yes	Yes
SNMP	Manage remotely using the simple network management protocol (SNMP)	No	Yes	Yes
Management Server	Manage with the management server	No	Yes	No
SES	Manage through SCSI-3 enclosure services	No	Yes	No
Web Tools	Manage remotely through graphical user interface	No	Yes	Yes

2.6.2 Hardware setup for switch management

To enable remote connection to the switch, the switch must have a valid IP address. Two IP addresses can be set; one for the external out-of-band Ethernet port and one for in-band Fibre Channel network access.

2.6.3 Managing with Telnet

To make a successful Telnet connection to a switch, the user needs:

- Switch name or IP address
- Username
- Password

Any host system that supports Telnet can be used to connect to the switch over the Ethernet. If the host supports a name server, the switch name can be used to effect the Telnet connection. If name service is not used to register network devices, then the IP address is used to connect to the switch. For example:

```
telnet [switch_name]
```

```
telnet 192.168.64.9
```

When the Telnet connection is made, the user is prompted for a user name and password. The following section defines the default user names and passwords supplied with the switch. Both of these can be changed by the switch administrator.

2.7 SAN standards

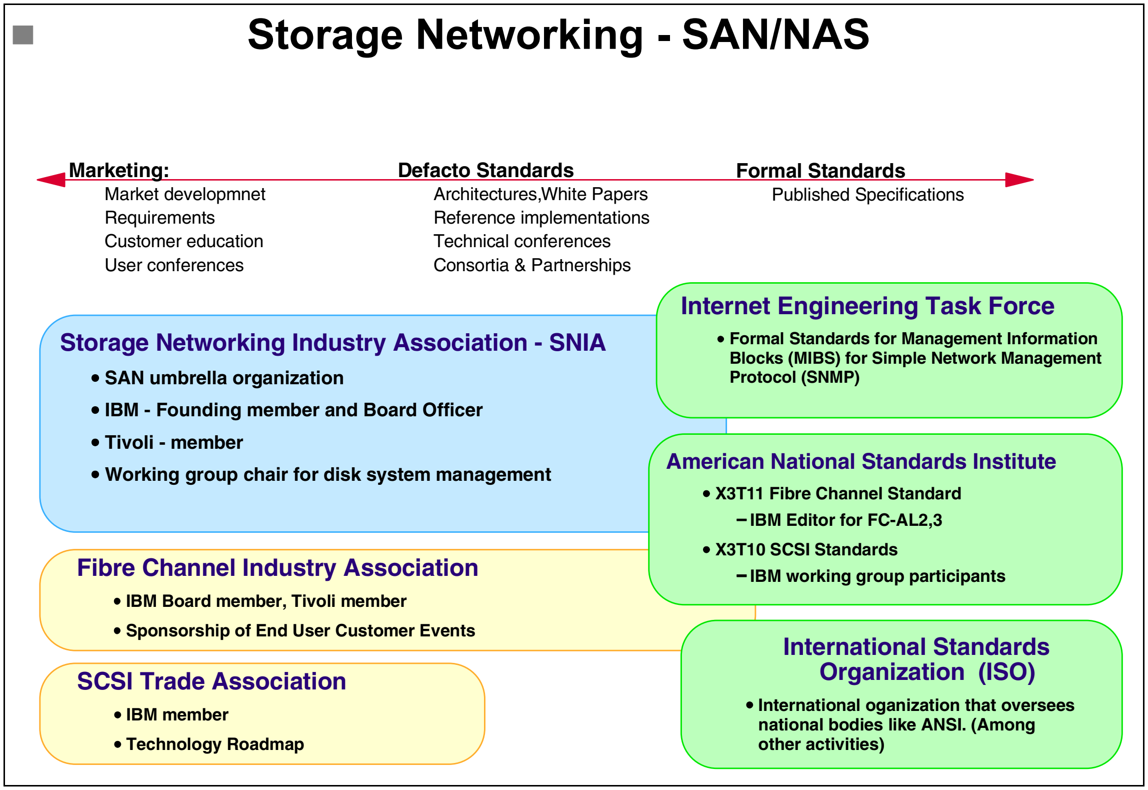
Given the strong drive towards SANs from users and vendors alike, one of the most critical success factors is the ability of systems and software from different vendors to operate together in a seamless way. Standards are the basis for the interoperability of devices and software from different vendors.

A good benchmark is the level of standardization in today's LAN and WAN networks. Standard interfaces for interoperability and management have been developed, and many vendors compete with products based on the implementation of these standards. Customers are free to mix and match components from multiple vendors to form a LAN or WAN solution. They are also free to choose from several different network management software vendors to manage their heterogeneous network.

The major vendors in the SAN industry recognize the need for standards, especially in the areas of interoperability interfaces and application programming interfaces (APIs), as these are the basis for wide acceptance of SANs. Standards will allow customers a greater breadth of choice, and will lead to the deployment of cross-platform, multi-vendor, enterprise-wide SAN solutions.

2.7.1 SAN industry associations and organizations

A number of industry associations, standards bodies, and company groupings are involved in developing, and publishing SAN standards. The major groups linked with SAN standards are shown in Figure 2-31.



Storage Networking - SAN/NAS

Marketing:
Market developmnet
Requirements
Customer education
User conferences

Defacto Standards
Architectures,White Papers
Reference implementations
Technical conferences
Consortia & Partnerships

Formal Standards
Published Specifications

Storage Networking Industry Association - SNIA

- SAN umbrella organization
- IBM - Founding member and Board Officer
- Tivoli - member
- Working group chair for disk system management

Internet Engineering Task Force

- Formal Standards for Management Information Blocks (MIBS) for Simple Network Management Protocol (SNMP)

American National Standards Institute

- X3T11 Fibre Channel Standard
  - IBM Editor for FC-AL2,3
- X3T10 SCSI Standards
  - IBM working group participants

Fibre Channel Industry Association

- IBM Board member, Tivoli member
- Sponsorship of End User Customer Events

SCSI Trade Association

- IBM member
- Technology Roadmap

International Standards Organization (ISO)

- International organization that oversees national bodies like ANSI. (Among other activities)

Figure 2-31 Groups involved in setting storage management standards

The roles of these associations and bodies fall into three categories:

- **Market development:** These associations are involved in market development, establishing requirements, conducting customer education, user conferences, and so on. The main organizations are the Storage Network Industry Association (SNIA); Fibre Channel Industry Association (merging the former Fibre Channel Association and the Fibre Channel Loop Community); and the SCSI Trade Association (SCSITA). Some of these organizations are also involved in the definition of defacto standards.
- **Defacto standards:** These organizations and bodies tend to be formed from two sources. They include working groups within the market development organizations, such as SNIA and FCIA. Others are partnerships between groups of companies in the industry, such as Jiro, Fibre Alliance, and the Open Standards Fabric Initiative (OSFI), which work as pressure groups towards defacto industry standards. They offer architectural definitions, write white papers, arrange technical conferences, and may reference implementations based on developments by their own partner companies. They may submit these specifications for formal standards acceptance and approval. The OSFI is a good example, comprising the five manufacturers of Fibre Channel switching products. In July 1999, they announced an initiative to accelerate the definition, finalization, and adoption of specific Fibre Channel standards that address switch interoperability.
- **Formal standards:** These are the formal standards organizations, like IETF, ANSI, and ISO, which are in place to review, obtain consensus, approve, and publish standards defined and submitted by the preceding two categories of organizations.

IBM and Tivoli Systems are heavily involved in most of these organizations, holding positions on boards of directors and technical councils and chairing projects in many key areas. We do this because it makes us aware of new work and emerging standards. The hardware and software management solutions we develop, therefore, can provide early and robust support for those standards that do emerge from the industry organizations into pervasive use. Secondly, IBM, as the innovation and technology leader in the storage industry, wants to drive reliability, availability, serviceability, and other functional features into standards. Following are the standards organizations in which we participate.

American National Standards Institute

American National Standards Institute (ANSI) does not itself develop American national standards. It facilitates development by establishing consensus among qualified groups. IBM participates in numerous committees, including those for Fibre Channel and storage area networks. For more information on ANSI, see its Web site at:

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http://www.ansi.org/
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INCITS

The International Committee for Information Technology Standards (INCITS) is the primary U.S. focus of standardization in the field of Information and Communications Technologies (ICT), encompassing storage, processing, transfer, display, management, organization, and retrieval of information. As such, INCITS also serves as ANSI's Technical Advisory Group for ISO/IEC Joint Technical Committee (JTC) 1. JTC 1 is responsible for International standardization in the field of Information Technology. From 1997 until 2001, INCITS operated under the name, Accredited Standards Committee, National Committee for Information Technology (NCITS). You'll find all their projects listed in 2.7.2, "List of evolved Fibre Channel standards" on page 79. For more information, see INCITS Web site at:

http://www.incits.org/

INCITS technical committee T11

Technical committee T11 retains overall responsibility for work in the area of "Device Level Interfaces" and does the proposals for Fibre Channel transport, Topology, Generic Services, and physical and media standards. The INCITS T11 committee is often referred to as the ANSI T11 group for short. Access to all proposals is available via the Web site at:

http://www.t11.org

Storage Networking Industry Association

Storage Networking Industry Association (SNIA) is an international computer industry forum of developers, integrators, and IT professionals who evolve and promote storage networking technology and solutions. SNIA was formed to ensure that storage networks become efficient, complete, and trusted solutions across the IT community. SNIA is accepted as the primary organization for the development of SAN standards, with over 125 companies as its members, including all the major server, storage, and fabric component vendors. SNIA also has a working group dedicated to the development of NAS standards, and is committed to delivering architectures, education, and services that will propel storage networking solutions into a broader market. IBM is one of the founding members of SNIA, and has senior representatives participating on the board and in technical groups. For additional information on the various activities of SNIA, see its Web site at:

http://www.snia.org/home

Fibre Channel Industry Association

The Fibre Channel Industry Association (FCIA) was formed in the autumn of 1999 as a result of a merger between the Fibre Channel Association (FCA) and the Fibre Channel Community (FCC). The FCIA currently has more than 150 members in the United States and through its affiliate organizations in Europe and Japan. The FCIA mission is to nurture and help develop the broadest market for Fibre Channel products. This is done through market development, education, standards monitoring, and fostering interoperability among members' products. IBM is a principal member of the FCIA.

Recently announced was the SANmark Qualified Program. The purpose of the program is to provide the industry with an objective indication of how Fibre Channel products perform against reasonable standards and to permit the use of the trademarked term *SANmark*, and any associated logo(s), in the identification and promotion of products meeting the published test indices.

The SANmark Qualified Program goals are to:

- Make Fibre Channel solutions easy to use, easy to install, manage, configure, diagnose, and troubleshoot
- Ensure that Fibre Channel continues to attain the highest performance and installed base maturity available in the market
- Proliferate heterogeneous shared SAN resources and heterogeneous management framework over WAN connections

For additional information on the various activities of FCIA, see its Web site at:

`http://www.fibrechannel.org/`

The SCSI Trade Association

The SCSI Trade Association (SCSITA) was formed to promote the use and understanding of small computer system interface (SCSI) parallel interface technology. The SCSITA provides a focal point for communicating SCSI benefits to the market, and influences the evolution of SCSI into the future. IBM is a founding member of the SCSITA. For more information, see its Web site at:

`http://www.scsita.org/`

InfiniBand (SM) Trade Association

The demands of the Internet and distributed computing are challenging the scalability, reliability, availability, and performance of servers. To meet this demand, a balanced system architecture with equally good performance in the memory, processor, and input/output (I/O) subsystems is required. A number of leading companies have joined together to develop a new common I/O specification beyond the current PCI bus architecture, to deliver a channel based, switched fabric technology that the entire industry can adopt. InfiniBand™ Architecture represents a new approach to I/O technology and is based on the collective research, knowledge, and experience of the industry's leaders. IBM is a founding member of InfiniBand (SM) Trade Association. For additional information, see its Web site at:

http://www.infinibandta.org/home

National Storage Industry Consortium

The National Storage Industry Consortium membership consists of over fifty US corporations, universities, and national laboratories with common interests in the field of digital information storage. A number of projects are sponsored by NSIC, including network attached storage devices (NASD), and network attached secure disks. The objective of the NASD project is to develop, explore, validate, and document the technologies required to enable the deployment and adoption of network attached devices, subsystems, and systems. IBM is a founding member of the NSIC. For more information, see its Web site at:

http://www.nsic.org/

Internet Engineering Task Force

The Internet Engineering Task Force (IETF) is a large, open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture, and the smooth operation of the Internet. It is responsible for the formal standards for the Management Information Blocks (MIB) and for Simple Network Management Protocol (SNMP) for SAN management. For additional information on IETF, see its Web site at:

http://www.ietf.org/

The IEEE Standards Association

The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) is a membership organization that produces standards which are developed and used internationally, serving today's industries with a complete portfolio of standards programs. For more information on the IEEE-SA, see its Web site at:

http://standards.ieee.org/sa/sa-view.html

Distributed Management Task Force

The DMTF is the industry organization that is leading the development, adoption, and unification of management standards and initiatives for desktop, enterprise, and Internet environments. Working with key technology vendors and affiliated standards groups, the DMTF is enabling a more integrated, cost-effective, and less crisis-driven approach to management through interoperable management solutions. DMTF has released its WBEM Specifications (CIM Operations over HTTP v1.1, Representation of CIM in XML v2.1, and the CIM DTD v2.1.1) in final status. You can visit the Web site at:

`http://www.dmtf.org`

2.7.2 List of evolved Fibre Channel standards

Table 2-8 lists all current T11 Fibre Channel projects that are either approved standards or in proposal status. For the most recent status, visit the T11 Web site at:

`http://www.t11.org`

Table 2-8 T11 projects

Acronym	Title	Status
10 Bit Interface TR	10-bit Interface Technical Report	X3.TR-18:1997
10GFC	Fibre Channel - 10 Gigabit	Project 1413-D
FC-10KCR	Fibre Channel - 10 km Cost-Reduced Physical variant	INCITS 326: 1999
FC-AE	Fibre Channel Avionics Environment	INCITS TR-31-2002
FC-AE-2	Fibre Channel - Avionics Environment – 2	Project 1605-DT
FC-AL	FC Arbitrated Loop	ANSI X3.272:1996
FC-AL-2	Fibre Channel 2nd Generation Arbitrated Loop	INCITS 332: 1999
FC-AV	Fibre Channel - Audio-Visual	ANSI/INCITS 356:2001
FC-BB	Fibre Channel – Backbone	ANSI NCITS 342

Acronym	Title	Status
FC-BB-2	Fibre Channel - Backbone – 2	Project 1466-D
FC-CU	Fibre Channel Copper Interface Implementation Practice Guide	Project 1135-DT
FC-DA	Fibre Channel - Device Attach	Project 1513-DT
FC-FG	FC Fabric Generic Requirements	ANSI X3.289:1996
FC-FLA	Fibre Channel - Fabric Loop Attachment	INCITS TR-20:1998
FC-FP	FC - Mapping to HIPPI-FP	ANSI X3.254:1994
FC-FS	Fibre Channel Framing and Signaling Interface	Project 1331-D
FC-FS-2	Fibre Channel - Framing and Signaling – 2	Project
FC-GS	FC Generic Services	ANSI X3.288:1996
FC-GS-2	Fibre Channel 2nd Generation Generic Services	ANSI INCITS 288
FC-GS-3	Fibre Channel - Generic Services 3	NCITS 348-2000
FC-GS-4	Fibre Channel Generic Services 4	Project 1505-D
FC-HBA	Fibre Channel - HBA API	Project 1568-D
FC-HSPI	Fibre Channel High Speed Parallel Interface (FC-HSPI)	INCITS TR-26: 2000
FC-LE	FC Link Encapsulation	ANSI X3.287:1996
FC-LS	Fibre Channel - Link Services	Project

Acronym	Title	Status
FC-MI	Fibre Channel - Methodologies for Interconnects Technical Report	INCITS TR-30-2002
FC-MI-2	Fibre Channel - Methodologies for Interconnects – 2	Project 1599-DT
FC-MJS	Methodology of Jitter Specification	INCITS TR-25:1999
FC-MJSQ	Fibre Channel - Methodologies for Jitter and Signal Quality Specification	Project 1316-DT
FC-PH	Fibre Channel Physical and Signaling Interface	ANSI X3.230:1994
FC-PH-2	Fibre Channel 2nd Generation Physical Interface	ANSI X3.297:1997
FC-PH-3	Fibre Channel 3rd Generation Physical Interface	ANSI X3.303:1998
FC-PH:AM 1	FC-PH Amendment #1	ANSI X3.230:1994/AM1:1996
FC-PH:DAM 2	FC-PH Amendment #2	ANSI X3.230/AM2-1999
FC-PI	Fibre Channel - Physical Interface	INCITS 352
FC-PI-2	Fibre Channel - Physical Interfaces – 2	Project
FC-PLDA	Fibre Channel Private Loop Direct Attach	INCITS TR-19:1998
FC-SB	FC Mapping of Single Byte Command Code Sets	ANSI X3.271:1996
FC-SB-2	Fibre Channel - SB 2	INCITS 349-2000
FC-SB-3	Fibre Channel - Single Byte Command Set – 3	Project 1569-D

Acronym	Title	Status
FC-SP	Fibre Channel - Security Protocols	Project 1570-D
FC-SW	FC Switch Fabric and Switch Control Requirements	INCITS 321:1998
FC-SW-2	Fibre Channel - Switch Fabric – 2	ANSI/INCITS 355-2001
FC-SW-3	Fibre Channel - Switch Fabric – 3	Project 1508-D
FC-SWAPI	Fibre Channel Switch Application Programming Interface	Project 1600-D
FC-Tape	Fibre Channel - Tape Technical Report	INCITS TR-24:1999
FC-VI	Fibre Channel - Virtual Interface Architecture Mapping	ANSI/INCITS 357-2001
FCSM	Fibre Channel Signal Modeling	Project 1507-DT
MIB-FA	Fibre Channel Management Information Base	Project 1571-DT
SM-LL-V	FC - Very Long Length Optical Interface	ANSI/INCITS 339-2000
SM-AMD	SAN Management - Attribute & Method Dictionary	Project 1606-DT
SM-MM	SAN Management - Management Model	Project 1606-DT

10 Gb/s

10GFC is a working draft for the extensions to the FC-PH and FC-PI standard to support a data rate of 10.2 Gb/s. The proposal includes five different physical interface types — three shortwave and two longwave solutions:

- SW Parallel interface: the data is spread over four parallel fiber links
- SW Serial interface: 10.2 Gb/s over a single fiber link
- SW Coarse Wavelength Division Multiplexed (CWDM): data is multiplexed over four wavelengths on a single fiber
- LW Serial interface: 10.2 Gb/s over a single fiber link
- LW CWDM: data is multiplexed over four wavelengths on a single fiber

The Fibre Channel Industry Association (FCIA) completed the core content of its proposed 10 Gb/s Fibre Channel standard. The forthcoming 10GFC specification leverages the work done by the IEEE P802.3ae Task Force and shares a common link architecture and common components with Ethernet and InfiniBand. The proposed 10GFC standard will span link distances from 15 m up to 10 km and offer direct support for native dark fiber (DWDM) and SONET/SDH, while preserving the Fibre Channel frame format and size for full backward compatibility.

3

SAN features

In this chapter we discuss some terminology and concepts that are derived from the Fibre Channel standards and frequently found in SAN device specifications and installations.

We also overview some common features and characteristics of the SAN environment, such as distance, applications, and the different platforms that can benefit from a SAN implementation.

3.1 Fabric implementation

We can build a SAN with a single switch and attached devices. However, as our fabric expands, we will eventually run out of ports. One possible solution is to move to a bigger switch or director, and another solution is to interconnect switches together to build a larger fabric. Another reason that we may need to interconnect switches or directors is to cover longer distances, for example, a building-to-building interconnection for backup and disaster recovery.

Note: It is not unusual to see directors referred to as switches. This is a statement as to the architecture that is employed *within* the director. That is to say, the director adheres to the Fibre Channel Switched Fabric (FC-SW) standard and employs the same switching protocol as a switch. There is no Fibre Channel “Director” Fabric standard! In this redbook, where something does not apply to both switches and directors equally, we make this distinction clear.

The diagram in Figure 3-1 shows two cascaded directors located at two different sites that can be up to 10 km apart. In this way all four servers can connect to both ESS devices.

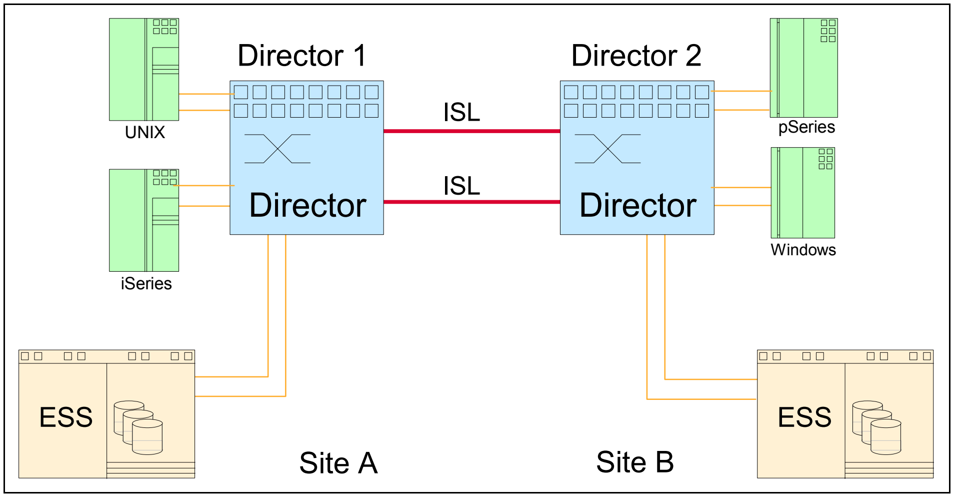

Figure 3-1 Cascading directors

3.1.1 Blocking

To support highly performing fabrics, the fabric components (switches or directors) must be able to move data around without any impact to other ports, targets, or initiators that are on the same fabric. If the internal structure of a switch or director cannot do so without impact, we end up with blocking.

Blocking means that the data does not get to the destination. This is opposed to congestion, where data will still be delivered, albeit with a delay. Switches and directors may employ a non-blocking switching architecture. Non-blocking switches and directors are the Ferraris on the SAN racetrack — they provide for multiple connections travelling through the internal components of the switch and director concurrently.

We illustrate this concept in Figure 3-2.

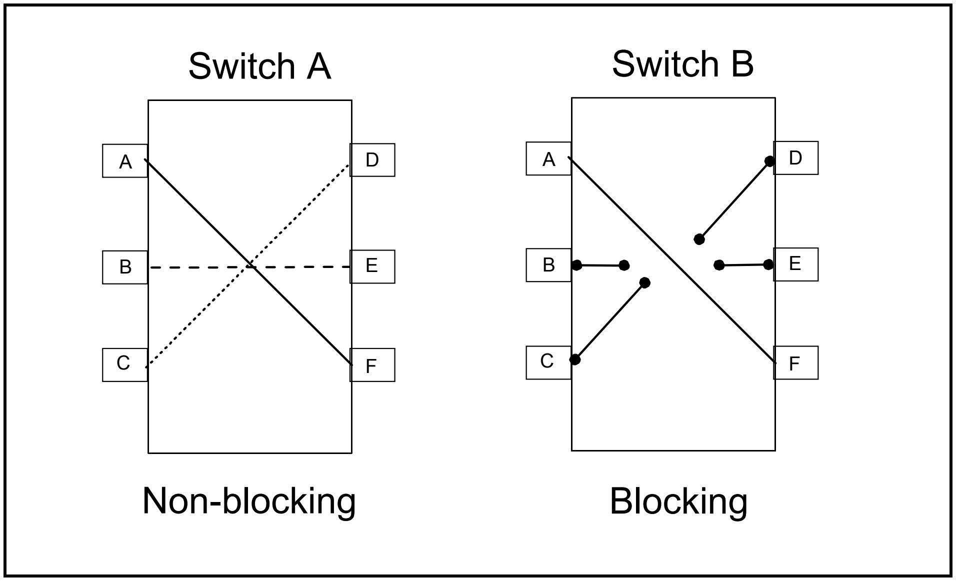

Figure 3-2 Non-blocking and blocking switching

In this example, non-blocking Switch A, port A speaks to port F, B speaks to E, and C speaks to D without any form of suspension of communication or delay; that is to say, the communication is not blocked. In the blocking Switch B, while port A is speaking to F, all other communication has been stopped or blocked.

3.1.2 Ports

The ports of a switch that connect to the devices N_Ports are called F_Ports. Coupling switches together introduces a new kind of connection, switch to switch. The port at which frames pass between switches within the fabric is called an E_Port.

A switch port will typically support one or more of the following Port Modes:

- F_Port (defined in the FC-PH standard)
- FL_Port (arbitrated loop connection defined in the FC-AL standard)
- E_Port (defined in the FC-SW standard).

A switch that only provides F_Ports and FL_Ports forms a non-expandable fabric. In order to be part of an expandable fabric the switch must have at least one port capable of E_Port operation.

A switch port that has the capability to support more than one port mode attempts to configure itself first as an FL_Port, then as an E_Port and finally as an F_Port, depending on which of the three modes are supported and the port it is connected to.

Switch ports that support both F_Port and E_Port modes are called G_Ports.

3.1.3 Inter-Switch Links

According to the FC-SW Fibre Channel standard, the link joining a pair of E_Ports is called an Inter-Switch Link (ISL).

ISLs carry frames originating from the node ports and those generated within the fabric. The frames generated within the fabric serve as control, management, and support for the fabric.

Before an ISL can carry frames originating from the node ports, the joining switches have to go through a synchronization process on which operating parameters are interchanged. If the operating parameters are not compatible, the switches may not join, and the ISL becomes “segmented”. Segmented ISLs cannot carry traffic originating on node ports, but they can still carry management and control frames.

Trunking

Depending on the estimated or measured traffic, you may connect some of your switches by parallel ISLs to share the load. The SAN standard routing protocol FSPF allows you to do so and use the cumulative bandwidth of all parallel ISLs (see Figure 3-3).

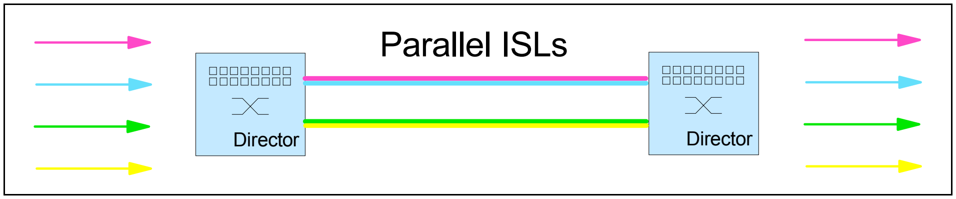

Figure 3-3 Parallel ISLs - low traffic

You need to be aware that load sharing reaches the boundary of its efficiency when servers send high amounts of data at the same time. As the switches dedicate the ISLs to the servers usually in a round-robin fashion, it may easily happen that one server occupies one ISL performing just a low rate of throughput and two other servers have to share the other ISL for their high rate of throughput (see Figure 3-4).

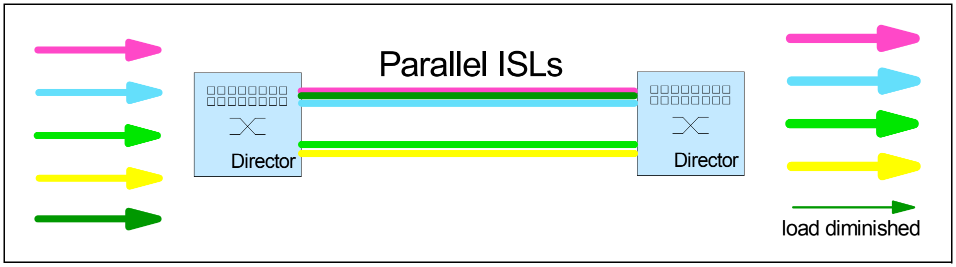

Figure 3-4 Parallel ISLs - high traffic

You may reduce, but not eliminate, this drawback by adding more ISLs in parallel; however, this may be far too expensive and subject to over-provisioning. Instead of this rather inflexible method of load *sharing*, switches may utilize a better way of load *balancing*. The implementation of load balancing is named trunking and is ideal for optimizing SAN performance (see Figure 3-5).

Each vendor of SAN switches will implement trunking in its own way. However, common to all their implementations is that transient workload peaks for one system or application are much less likely to impact the performance of other devices in the SAN fabric.

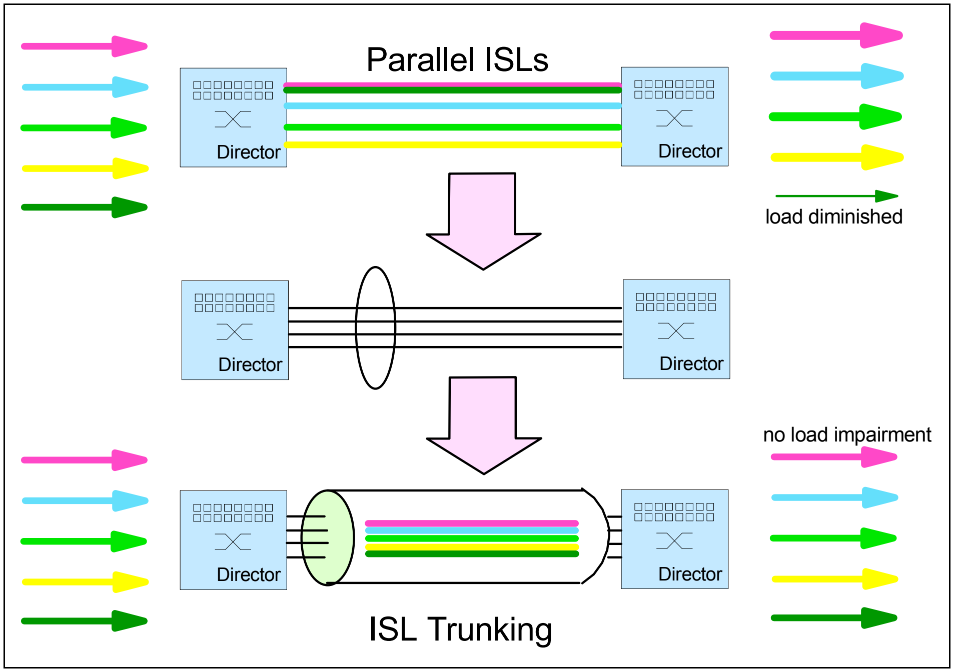

Figure 3-5 ISL Trunking

Load sharing or load balancing: Parallel ISLs always shared load or traffic in a “rough” server-oriented way: next server or next available ISL, regardless of the amount of traffic each server is causing. Load balancing provides the means to find an effective way to use all of the cumulative bandwidth of these parallel ISLs.

Oversubscribing the fabric

We can have several ports in a switch that can communicate with a single port, for example, several servers sharing a path to a storage device. In this case the storage path determines the maximum data rate that all servers can get, and this is usually given by the device and not the SAN itself.

When we start cascading switches, communication between switches are carried by ISLs, as previously stated. It is possible that several ports in one switch need to simultaneously communicate with ports in the other switch through a single ISL. In this case it is possible that the connected devices are able to sustain a data transfer rate higher than 100 MB/s, so the throughput will be limited to what the ISL can handle, and this may impose a throttle or roadblock within the fabric.

We use the term oversubscription to describe a situation when we have several ports trying to communicate with each other, and when the total throughput is higher than what that port can provide. Oversubscription, in itself, is not a bad thing. It is actually good, because it would be too cost prohibitive to dedicate bandwidth and resources for every connection. The problem arises if the oversubscription results in congestion. Congestion occurs when there is not enough bandwidth available for the application or connection. This can happen on storage ports and ISLs.

When designing a SAN, it is important to consider the possible traffic patterns to determine the possibility of oversubscription and which patterns may result in congestion. For example, traffic patterns during backup periods may introduce oversubscription that can affect performance on production systems. In some cases this is not a problem that may even be noticed at first, but as the SAN fabric grows, it is important not to ignore this possibility.

Fabric shortest path first

According to the FC-SW-2 standard, Fabric Shortest Path First (FSPF) is a link state path selection protocol. FSPF keeps track of the links on all switches in the fabric and associates a cost with each link. The protocol computes paths from a switch to all the other switches in the fabric by adding the cost of all links traversed by the path, and choosing the path that minimizes the cost.

For example, as shown in Figure 3-6, if we need to connect a port in switch A to a port in switch D, it will take the ISL from A to D. It will not go from A to B to D, nor from A to C to D.

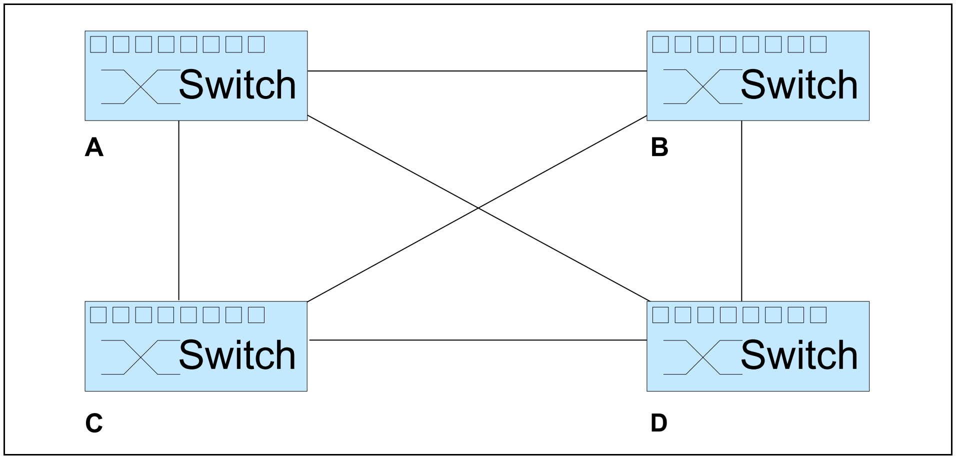

Figure 3-6 Four-switch fabric

This is because FSPF is currently based on the hop count cost.

The collection of link states (including cost) of all switches in a fabric constitutes the topology database (or link state database). The topology database is kept in all switches in the fabric, and they are maintained and synchronized to each other. There is an initial database synchronization, and an update mechanism. The initial database synchronization is used when a switch is initialized, or when an ISL comes up. The update mechanism is used when there is a link state change, for example, an ISL going down or coming up, and on a periodic basis. This ensures consistency among all switches in the fabric.

If we look again at the example in Figure 3-6, and we imagine that the link from A to D goes down, switch A will now have four routes to reach D:

- A-B-D
- A-C-D
- A-B-C-D
- A-C-B-D

A-B-D and A-C-D will be selected because they are the shortest paths based on the hop count cost. The update mechanism ensures that switches B and C will also have their databases updated with the new routing information.

Load balancing

The standard does not provide for load balancing when there are multiple paths of the same cost, so it is up to the switch vendor to establish routing algorithms to balance the load across ISLs. The potential routes are stored in routing tables.

Some vendors allow you to adjust the cost of traversing the fabric, and it is wise to check with each vendor as to the adjustments that can be made. Some vendors also allow you to define static routes. Again, it is wise to check with each vendor regarding what you can do to affect the traffic that flows over ISLs.

The balancing is usually done at initialization, assigning the same number of paths to each ISL. However, having the same number of paths does not mean having the same bandwidth requirements. We may end up with different connections that have high performance requirements being assigned to the same ISLs; while other ISLs are not being used due to inactive connections. Current implementations do not include dynamic load balancing, although this is expected to change over time.

Due to the potential performance impact of oversubscribing ISLs, it is recommended to have high volume traffic inside a switch or director. When cascading is not an option, the number of ISLs should be planned, and should take into consideration the expected traffic through them under different conditions, for example, production workload, and backup workload. In the absence of quantitative data, if you plan for the peak workload, that may be as good a rule of thumb as any.

When ISL oversubscription is detected, one solution is to add additional ISLs. It can be done concurrently, and the new path will be automatically included in the routing tables.

3.1.4 RSCN

The Registered State Change Notification (RSCN) is part of the Extended Link Service (ELS) in the Fibre Channel protocol. It was defined within the Fabric Loop Attachment group (FC-FLA) as a replacement for State Change Notification (SCN). You may consider RSCN similar to SCN plus the opportunity as a Fibre Channel device to register (subscribe) to that service or not. RSCN, like SCN, is used to notify FC devices about the status changes of other ports which may be of interest for them. For example, when a storage port becomes active or inactive, the switch will let the registered servers know by issuing a RSCN notification to them. RSCN notifications flow either from:

- Node ports to switch — by addressing the well-known fabric controller address of 0xFF FF FD (FC-FLA definition modified in FC-DA)
- Switch to switch — by addressing the fabric controller (FC-FLA definition modified in FC-MI-2)
- Switch to node port — from fabric controller to node fabric address (FC-FLA definition modified in FC-MI-2)

After a server has been notified via RSCN that another SCSI storage device has come online, the server may try and attach to that storage by performing a login to it. Or if the server was notified that some storage has gone offline, the server may like to verify the current status of that device. Without RSCN, in the latter case, the server probably wouldn’t find out until it was sending SCSI-READs or WRITEs to that storage. These are the types of RSCNs:

- **Fabric Format:** Sent when a zone configuration is activated or deactivated or when and ISL in a fabric goes up or down.
- **Port Format:** Occurs when a device logs in or out of a fabric.
  - Sent to local devices on the same switch.
  - Sent to remaining switches in the fabric.
- **Area Format:** Occurs when an entire arbitrated loop goes up or down.
- **Domain Format:** Occurs when a switch is added or removed from a fabric.

3.2 Classes of service

In Fibre Channel, we have a combination of traditional I/O technologies with networking technologies.

We need to keep the functionality of traditional I/O technologies to preserve data sequencing and data integrity, and we need to add networking technologies that allow for a more efficient exploitation of available bandwidth.

Based on the methodology with which the communication circuit is allocated and retained, and in the level of delivery integrity required by an application, the Fibre Channel standards provide different classes of service:

3.2.1 Class 1

In a Class 1 service, a dedicated connection between source and destination is established through the fabric for the duration of the transmission. Each frame is acknowledged by the destination device back to the source device. This class of service ensures the frames are received by the destination device in the same order they are sent, and reserves full bandwidth for the connection between the two devices. It does not provide for a good utilization of the available bandwidth, since it is blocking another possible contender for the same device. Because of this blocking and the necessary dedicated connections, Class 1 is rarely used.

3.2.2 Class 2

In a Class 2 service there is no dedicated connection; each frame is sent separately using switched connections allowing several devices to communicate at the same time. For this reason Class 2 is also called “connectionless”. Although there is no dedicated connection, each frame is acknowledged from destination to source to confirm receipt. The use of delivery acknowledgments in Class 2 allows for quickly identifying communications problems at both the sending and receiving ports. Class 2 makes a better use of available bandwidth since it allows the fabric to multiplex several messages on a frame by frame basis. As frames travel through the fabric they can take different routes, so Class 2 does not guarantee in-order delivery. Class 2 relies on upper layer protocols to take care of frame sequence. The use of acknowledgments reduced available bandwidth which needs to be considered in large scale busy networks.

3.2.3 Class 3

Like Class 2, there is no dedicated connection in Class 3, the main difference is that received frames are not acknowledged. The flow control is based on BB Credit, but there is no individual acknowledgement of received frames. Class 3 is also called “datagram connectionless” service. It optimizes the use of fabric resources, but it is now up to the upper layer protocol to ensure all frames are received in the proper order, and to request to the source device the retransmission of any missing frame. Class 3 is the commonly used class of service in Fibre Channel networks.

Note: Classes 1, 2, and 3 are well defined and stable. They are defined in the FC-PH standard.

IBM 2109 switches support Class 2 and Class 3 service.

3.2.4 Class 4

Class 4 is a connection oriented service like Class 1, but the main difference is that it allocates only a fraction of the available bandwidth of a path through the fabric that connects two N_Ports. Virtual Circuits (VCs) are established between N_Ports with guaranteed Quality of Service (QoS) including bandwidth and latency. The Class 4 circuit between two N_Ports consists of two unidirectional VCs, not necessarily with the same QoS. An N_Port may have up to 254 Class 4 circuits with the same or different N_Port. Like Class 1, Class 4 guarantees in-order frame delivery and provides acknowledgment of delivered frames, but now the fabric is responsible for multiplexing frames of different VCs. Class 4 service is mainly intended for multimedia applications such as video and for applications that allocate an established bandwidth by department within the enterprise. Class 4 was added in the FC-PH-2 standard.

3.2.5 Class 5

Class 5 is called isochronous service and it is intended for applications that require immediate delivery of the data as it arrives, with no buffering. It is not clearly defined yet. It is not included in the FC-PH documents.

3.2.6 Class 6

Class 6 is a variant of Class 1 known as multicast class of service. It provides dedicated connections for a reliable multicast. An N_Port may request a Class 6 connection for one or more destinations. A multicast server in the fabric will establish the connections and get the acknowledgment from the destination ports, and send it back to the originator. Once a connection is established it should be retained and guaranteed by the fabric until the initiator ends the connection. Only the initiator can send data and the multicast server will transmit that data to all destinations.Class 6 was designed for applications like audio and video requiring multicast functionality. It appears in the FC-PH-3 standard.

3.2.7 Class F

Class F Service is defined in the FC-SW and FC-SW2 standard for use by switches communicating through ISLs. It is a connectionless service with notification of non-delivery between E_Ports, used for control, coordination and configuration of the fabric. Class F is similar to Class 2 since it is a connectionless service, the main difference is that Class 2 deals with N_Ports sending data frames, while Class F is used by E_Ports for control and management of the fabric.

3.2.8 Communication

FC-2 is the protocol level that defines protocol signaling rules and defines the organization or structure of Fibre Channel communications. This structure allows for efficient flow control and allows the network to quickly identify where a network error is occurring. The following describes the levels within this structure, they are listed according to size from the largest to the smallest.

- **Exchanges:** The highest level Fibre Channel mechanism used for communication. An exchange contains one or more non-concurrent sequences being exchanged between a pair of Fibre Channel ports.
- **Sequences:** A sequence is a collection of frames related to one message element or information unit.
- **Frames:** A Fibre Channel frame consists of maximum 2112 bytes of data. It is considered as a basic unit of data transmission. It consists of a start delimeter, destination and source address, protocol metadata, data payload, CRC (error check value) and an end delimeter.
- **Words:** An addressable unit of data in memory. The smallest Fibre Channel data element consisting of 40 serial bits representing either a flag (K28.5) plus 3 encoded data bytes (10 encoded bits each) or four 10-bit encoded data bytes. An *ordered set* is a 4-byte transmission word that has the special character, K28.5 as its first character and 3 bytes used to define the meaning or function of the ordered set. They either identify the start of frame, the end of frame, or occur between Fibre Channel frames.

3.2.9 Solutions

The main support for Fibre Channel development came from the workstation market. While in the mainframe platform the I/O channels have evolved allowing storage attachment and sharing through multiple high speed channels, and fiber optic cabling was introduced with ESCON®, workstations have been using SCSI as the common interface for storage attachment.

For storage interconnections, a SCSI interface had been traditionally used, but as data volumes and performance requirements increased, SCSI limitations started to surface: bulky cables, shared bus architecture that limits performance due to bus arbitration, limited distance of up to 25 m, and limited addressing of up to 15 targets. The continual growth of storage capacity requirements, data sharing needs and performance issues, made clear that it was necessary to overcome SCSI limitations. IBM introduced the IBM Serial Storage Architecture, and the IBM 7133 Disk Storage that solved many of the limitations of SCSI devices.

Another solution was the Fibre Channel interface. Mapping SCSI over the Fibre Channel Protocol was the solution that allowed access to multiple storage devices, extended distances, reduce cable bulk, and sharing of devices. Initially Fibre Channel arbitrated loop (FC-AL) was implemented to connect disk devices to hosts, and provided many benefits like smaller cables and connectors, faster data transfers and longer distances. Today, the arbitrated loop solution may still work for a department or workgroup, but does not offer the performance and connectivity required by an enterprise SAN, so different vendors offer Fibre Channel HBAs which provide for point-to-point connection, as well as connections to a Fibre Channel switched fabric.

These are some of the many reasons to implement a SAN fabric implementation:

- **Storage consolidation:** Storage devices can be shared with more servers without increasing the number of ports in the device.
- **Clustering:** For high availability solutions, a SAN allows shared storage connections and provides for longer distances between devices.
- **LAN free backup:** The ability to consolidate tape drives and tape libraries and share them among several backup hosts provides the opportunity to optimize the utilization of the tape drives. The result is more data can be backed up with the same number of, or less, drives.

To expand the benefits of a SAN across longer distances and allow more companies to realize the benefits of a SAN, several projects are currently underway. One solution that may make use of Fibre Channel is the Internet Protocol (IP). It requires an upper layer protocol that takes care of sending IP packets as Fibre Channel Sequences. One project in the T11 committee deals with Fibre Channel link encapsulation (FC-LE). As a result of this project’s work, there is a new protocol known as FC-IP, or FCIP, that will allow for greater distances by IP encapsulating the Fibre Channel protocol.

A new protocol called iSCSI will enable SCSI commands to be packaged and sent over existing IP networks. This will allow companies that currently do not have the resources for a Fibre Channel network to build a SAN utilizing their existing IP network.

Example applications that exploit SANs

Today, we have information available in many different forms: text, images, audio, and video, which we usually refer to as multimedia. Given the storage capacity and performance levels that computer systems are able to provide today, and what can be expected in the future, it is becoming practical to store, distribute, and retrieve more information in digital form. This can dramatically increase the amount of data stored, the transmission throughput, and the sharing requirements.

SANs can fulfill many of the demands of multimedia applications. Some examples of these are described in the following sections.

Video editing

Digital video editing is usually performed in standard computers with specialized video boards. Due to the size of the video files they have to handle, workstations normally have big and fast local storage devices but are interconnected by a relatively low bandwidth LAN. Local copies must be made of the files to be worked on, and once again when the work is finished, either from a server through the LAN or using removable media.

Interconnecting all workstations and storage by means of a SAN has the following advantages:

- **Bandwidth:** A properly designed SAN can provide enough bandwidth for the workstations to access the data in shared storage eliminating the need and the time required for local copies.
- **Storage efficiency:** Consolidating storage in a single pull allows each workstation have the amount required for each task eliminating excess storage in each workstation.
- **Reliability:** Installing fault tolerant storage like RAID arrays and being able to perform simultaneous centralized backups and restores.
- **Workstation flexibility:** A task initiated in one workstation can be continued in another one. It is also possible to introduce a new platform and share existing data. This also eliminates the workstation as a single point of failure.
- **Location flexibility:** SAN distances allow workstations to be far apart from each other, making it possible to have some workstations in special locations, like soundproof rooms.
- **Simultaneous viewing:** The work in progress can be monitored without interruptions to the creative staff.
- **Separation of duties:** Creative staff can concentrate in their work leaving repetitive tasks like digitizing material and recording output to tape to other personnel. This can also help consolidating and saving additional equipment like VCRs.

In order to allow several users to share the storage and working copies simultaneously, some kind of management software is required.

Pre-press

Some of the characteristics of today's graphic industry are:

- **Multiple parties involved:** Printing facilities, advertising agencies, graphic designers, clients.
- **Gigantic size files:** Raster image processors (RIPs) and open pre-press interface (OPI) applications that feed computer to plate (CTP) devices often generate files in the gigabyte range, especially when dealing with large images at 1200 dpi resolution, making LANs too slow for reasonable file transfer times.
- **Mixed platforms:** High end graphic workstations running on Apple Macintosh workstations running Windows NT® or 2000, application and file servers running UNIX.

LANs have been successfully handling the mixed platform environment, but as file sizes have increased, LAN speed has become the bottleneck.

SANs can also handle the mixed platform environment and not only offer a greater bandwidth, but also reduce the processor overhead to move the larger data files. This makes it possible to connect the different workstations directly to shared storage and eliminates the need for making local copies of large files.

Video distribution

There is a lot of research in process related to multimedia systems. It deals with storing and transmitting large amounts of time critical data between storage systems and end users.

Some of the characteristics of a video server are:

- Huge amount of data stored
- Large number of potential concurrent users
- Real time requirements to allow all users receive a jitter free video signal
- User interaction, such as title selection, play, pause, stop
- Availability 24 hours x 365 days required
- Multiple server configurations to be able to handle all potential users
- Multiple storage devices to handle the amount of data stored

Without entering into the design considerations of such a system, SANs offer the capacity of handling the multiple server, multiple storage configuration with the bandwidth, the high availability, and the scalability characteristics required by these kinds of applications.

3.3 Distance

Fibre Channel allows for much longer distances than the 25 m limit of SCSI links. Currently supported distances are:

- **Short-wave laser*:*** Up to 500 m (50 µm fiber), 300 m (62.5 µm fiber)
- **Long-wave laser*:*** Up to 10 km (9 µm single-mode fiber).

When longer distances are required, there are different options, for example, extenders, protocol converters, or Dense Wave® Division Multiplexors (DWDM), and selection will depend on the available links between the two locations, distance and budget.

The chart in Figure 3-7 compares the distances that can be reached by different alternatives.

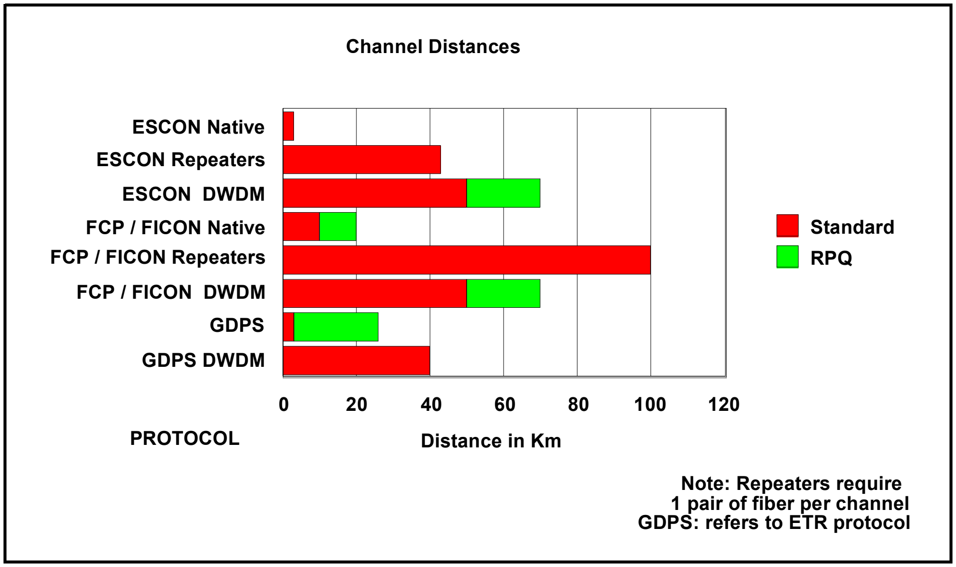

Figure 3-7 Channel distances comparison

Some distance solutions convert FCP to several OC3 or ATM channels, route the signals through telco lines, and reconvert the signals at the other end. These can reach hundreds or thousand of miles. By using repeaters and dedicated fibers, we can get distances of about 100 km. DWDM allows us to send several channels over the same fiber.

Figure 3-8 shows an example of a distance solution for tape backup, using CNT protocol converters. SCSI and FC links are multiplexed and transmitted over Telco lines to the remote site.

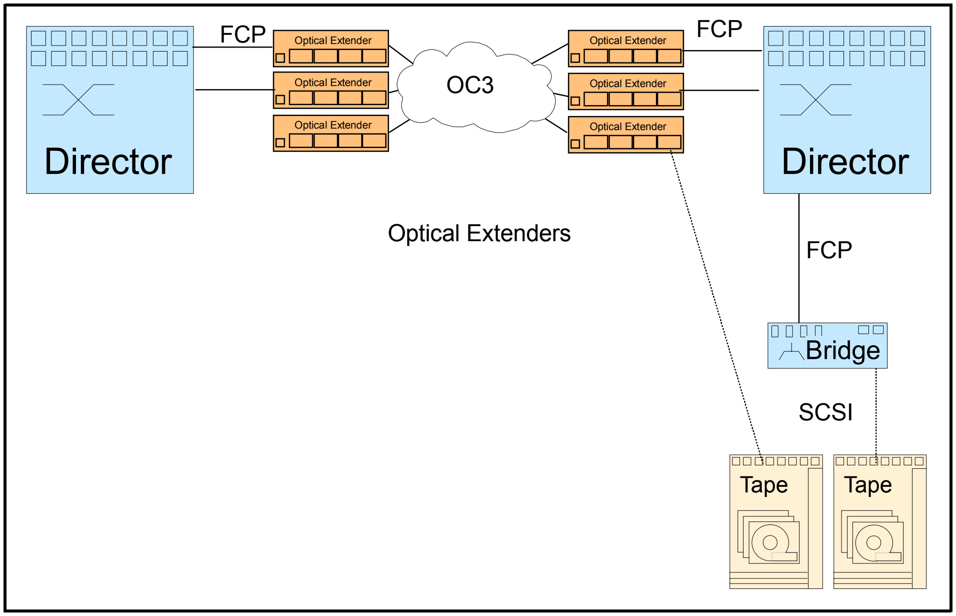

Figure 3-8 CNT distance solution

3.3.1 Dark fiber

Dark fiber is a dedicated, end-to-end, fiber optic cable that can be used without additional equipment up to 10 kilometers for longwave transceivers, or may require the use of extenders or repeaters, either external or internal in some directors, for longer distances. By using dark fiber, we can get the most direct connection and full bandwidth, but the down side is the cost of the dedicated fiber links.

Figure 3-9 shows an example of a solution using Finisar extenders. It is purely a fiber solution, but requires a pair of dark fibers between the sites for each link.

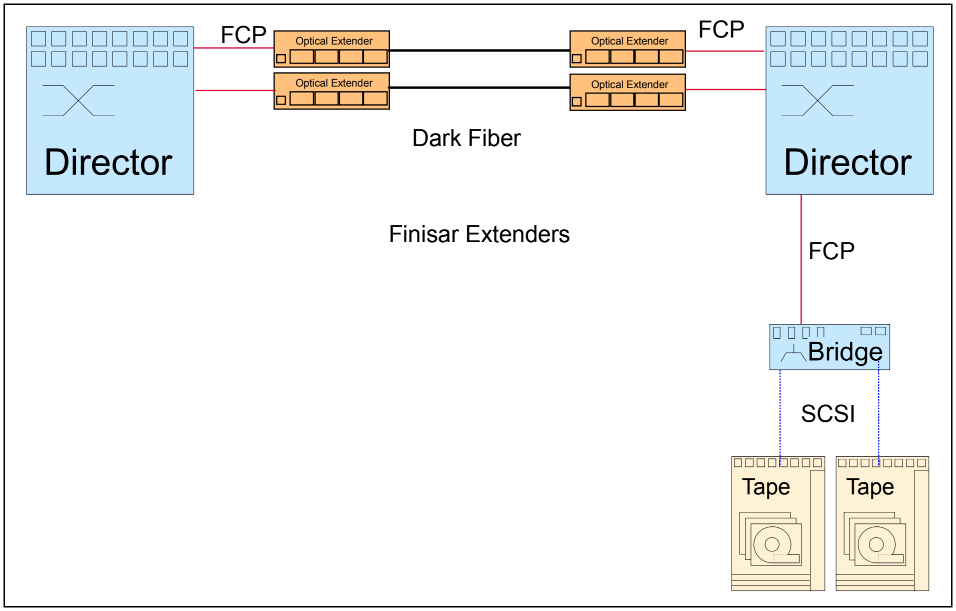

Figure 3-9 Distance solution with Finisar extenders

3.3.2 Dense Wavelength Division Multiplexing

Dense Wavelength Division Multiplexing (DWDM) allows several fiber optic signals to be multiplexed and sent over the same fiber optic cable at long distances reducing cabling requirements.

The original fiber optic signals are converted into electrical signals. The electrical signals are then converted back to different wavelength fiber optic signals. At the receiving end, the signals are optically filtered, converted back to the original signal type, and sent to the connecting device.

In Figure 3-10 we show an example of DWDM point-to-point configuration.

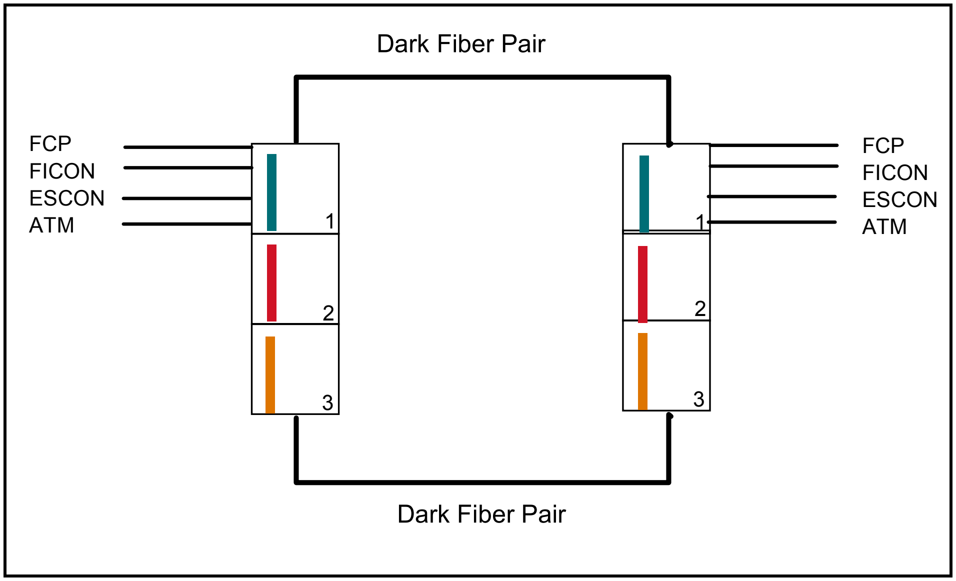

Figure 3-10 DWDM point-to-point configuration

To ensure redundancy and high availability, the two cables must go through completely different paths. They must enter the building at different entry points and follow different channels inside the building. When going out of their own building and campus, consider obtaining the links through different carriers.

In contrast to Figure 3-10 on page 103, which shows a simplified representation of a point-to-point configuration; the other possible configuration is the hubbed ring configuration. This is shown in Figure 3-11.

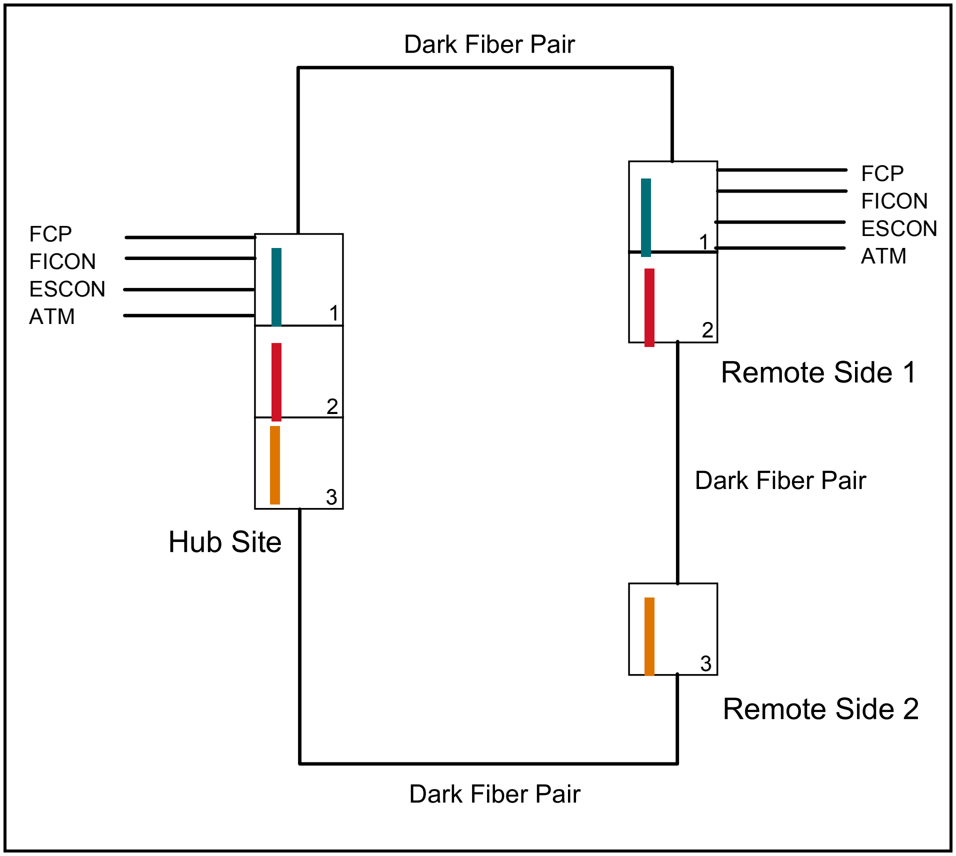

Figure 3-11 DWDM hubbed ring configuration

3.3.3 Primary and secondary routes

From an availability standpoint, it is essential that redundant links do not have common points of failure. It is very important that the carrier knows the physical routes the links are following, and that they are not only independent with regard to the transmission equipment, but also geographically apart. This introduces the possibility of different link lengths and different signal travel times.

We discuss the concepts associated with SAN distance solutions in *Introduction to SAN Distance Solutions*, SG24-6408.

3.4 Time-out values

Longer distances introduce other factors to consider in the SAN design, one of which is latency. The latency increases due to the time needed for the signal to travel the longer links, and has to be added to the normal latency introduced by switches and/or directors. Another point is that the time-out values should allow for increased travel times. For this reason, parameters such as the E_D_TOV and R_A_TOV have to be evaluated.

The FC-PH standard defines three time-out values used for error detection and recovery:

R_T_TOV

This is the Receiver Transmitter time-out value. It is used by the receiver logic to detect Loss of Synchronization with the transmitter. It has a fixed value of 100 ms.

E_D_TOV

This is the Error Detect time-out value. It represents the period in which a response should come back for a timed event. For example, during data transmission it represents a time-out value for a data frame to be delivered, the receiving port to transmit a response and the response be received by the initiator. E_D_TOV can normally be configured. The selected value should consider configuration and switch characteristics.

E_D_TOV is used in class of services 1 and 2, since class 3 does not check for acknowledgment.

R_A_TOV

This is the Resource Allocation time-out value. It is used as a time-out value during the recovery process. It should be set to E_D_TOV plus twice the maximum time a frame may be delayed within a fabric and still be delivered.

3.4.1 Time-out value settings

Without entering into the details of error detection and recovery, it is important to know the consequences of a wrong time-out value setting. Small E_D_TOV values may affect performance due to sequences being timed out and retried when they can still be correctly finished; too small R_A_TOV values may cause duplicated frames during recovery. On the other hand if the values are too long, error detection and recovery may be delayed when it is needed.

Switch manufacturers provide default values that should work fine for normal distances (up to 10 km). Delay considerations should be taken into account for extended distances. Each kilometer of fiber adds approximately 5 microseconds delay. Also the delay introduced by repeaters or extenders should be considered.

It is wise to check with each vendor as to what these values should, or need, to be set to in a fabric.

3.5 Buffers

Ports need memory, or “buffers”, to temporarily store frames as they arrive and until they are assembled in sequence, and delivered to the upper layer protocol.

The number of buffers (the number of frames a port can store) is called its “Buffer Credit”.

BB_Credit

During login, N_Ports and F_Ports at both ends of a link establish its Buffer to Buffer Credit (BB_Credit).

EE_Credit

During login all N_Ports establish End to End Credit (EE_Credit) with each other.

During data transmission, a port should not send more frames than the buffer of the receiving port can handle before getting an indication from the receiving port that it has processed a previously sent frame. Two counters are used for that purpose. BB_Credit_CNT and EE_Credit_CNT, and both are initialized to 0 during login.

Each time a port sends a frame, it increments BB_Credit_CNT and EE_Credit_CNT by 1. When it receives R_RDY from the *adjacent* port it decrements BB_Credit_CNT by 1, when it receives ACK from the *destination* port it decrements EE_Credit_CNT by 1. Should at any time BB_Credit_CNT become equal to the BB_Credit, or EE_Credit_CNT become equal to the EE_Credit of the receiving port, the transmitting port has to stop sending frames until the respective count is decremented.

The previous statements are true for Class 2 service. Class 1 is a dedicated connection, so it does not care about BB_Credit and only EE_Credit is used (EE Flow Control). Class 3 on the other hand is an unacknowledged service, so it only uses BB_Credit (BB Flow Control), but the mechanism is the same on all cases.

Here we can see the importance that the number of buffers has in overall performance. We need enough buffers to make sure the transmitting port can continue sending frames without stopping in order to use the full bandwidth.This is particularly true with distance.

BB_Credit considerations for long distance

BB_Credit needs to be taken into consideration on Fibre Channel devices that are several kilometers apart from each other and you need to know the distance separating the adjacent partners. We will assume that Fibre Channel devices A and B are connected by a 10 km fiber optic cable, as shown in Figure 3-12.

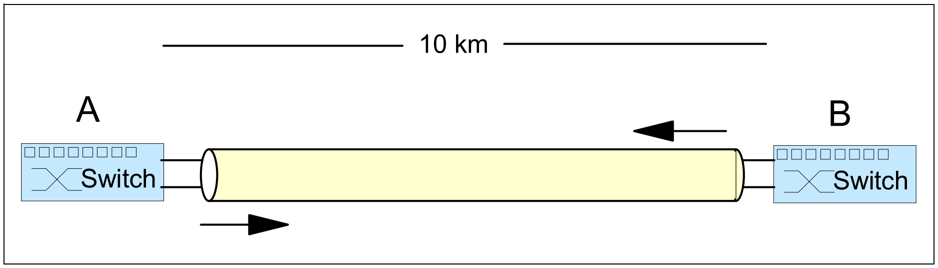

Figure 3-12 Adjacent FC devices

Light travels at approximately 300,000 km/s through a vacuum and at about 200,000 km/s through glass fiber. Latency is the inverse function of speed — so the optical signal of a Fibre Channel frame ends up with a latency of 5 ns/m.

$$latency = \frac{1}{speed} = \frac{1}{0.2\,\mathrm{exp}\,9\frac{m}{s}} = 5\,\mathrm{exp}{-9}\frac{s}{m} = 5\frac{ns}{m}$$

Light has a finite speed, and we need to take that into account when we figure out the maximum amount of frames that will be in transit over the fiber optic cable from A to B. A distance of 10 km over Fibre Channel means a round-trip of 20 km in total. The optical signal takes 100 µs propagation time (t_p) to travel that round-trip.

$$t_p = distance \times latency = 20\,\mathrm{exp}\,3\,m \times 5\,\mathrm{exp}{-9}\frac{s}{m} = 100\,\mathrm{exp}{-6}\,s = 100\,\mu s$$

That is the shortest possible time that A can expect to get an R_RDY back from B which, once received, signals that more frames can be sent.

Round-trip: We assume a data frame is sent from *A* and when it arrives at *B* a Receiver Ready (R_RDY) travels back to *A*. So for our equations, it is based on one frame which would make the round-trip.

Fibre Channel frames are usually 2 KB large, but because of 8b/10b encoding, they will become larger, as the encoding causes 1 byte to become 10 bits. Sending 2 KB Fibre Channel frames over fiber optic cable with 1 Gb/s bandwidth computes to a sending time (t_s) of 20 µs per frame. In other words: 20 µs is the time *A* needs to send 2000 bits.

$$t_s = \frac{Framelength}{Bandwidth} = \frac{20\,\mathrm{exp}3\,b}{1\,\mathrm{exp}9\frac{b}{s}} = 2\,\mathrm{exp}{-6}\,s = 20\mu s$$

To give an idea of how long a Fibre Channel frame spreads out on the fiber optic cable link, in 20 µs the light travels 4000 m (l), so the 2 KB frame occupies 4 km of fiber optic cable from the first bit transmitted to the last bit transmitted.

$$l = t_s \times speed = 20\,\mathrm{exp}{-6}\,s \times 0.2\,\mathrm{exp}9\frac{m}{s} = 4\,\mathrm{exp}3\,m = 4000m$$

The ratio between propagation time and sending time gives us the maximum amount of frames which *A* may send out before *B's* response would arrive back at *A*.

$$BB\_Credit = \frac{t_p}{t_s} = \frac{100\mu s}{20\mu s} = 5$$

So, *A* may send out five consecutive frames to fill up the whole Fibre Channel during the time it is waiting for a response from *B*. In order to do so, *A* needs to hold at least 5 BB_Credits to use the Fibre Channel effectively. Distances in the range of a few hundred meters and below are not usually effected. It becomes an area for consideration with longer distances in the region of 50-100 km or more when extending Fibre Channel links over DWDM or ATM. To guarantee the same effectiveness for the optical signal's propagation time for a 100 km distance, you would need to make sure that *A* has 50 BB_Credits available. Doubling the bandwidth of the fiber optic link from 1 Gb/s to 2 Gb/s means there may be twice as many Fibre Channel frames on the link at the same time and so we will need twice as many BB_Credits to reach the same efficiency. That is theoretically 100 BB_Credits on a 100 km, 2 Gb/s fiber optic link.

Practically speaking, you may not need that much BB_Credit, as it is unlikely that the FC device will fill up the Fibre Channel 100% over a sustained period.

3.6 Data protection

Since data is the most valuable asset for any organization and data availability is a primary concern, independently of the measures taken to ensure backup and recovery it is fundamental to maximize data availability for, and from, the primary storage device.

3.6.1 RAID

One of the common methods used to protect data in case of disk drive failures is RAID (Redundant Array of Independent Disks).

RAID is an architecture designed to improve data availability by using arrays of disks together with data striping methodologies.

There are different RAID levels according to the methodology implemented. The original classification described RAID-1 to RAID-5. Later on, other levels were added like RAID-0, RAID-0+1, RAID-6 and RAID-10. Listed below are the most prevalent RAID types in use today:

- **RAID 0 (striping):** Striping of data across separate disks. RAID-0 does not provide any redundancy, it is only used for performance.
- **RAID 1 (mirroring):** Two copies of the data are written to separate disks. In case one disk fails, the data is still available from the other copy. Twice the number of disk drives are required to store the data.
- **RAID 5:** An array of *n* drives is formed. Records of data are striped in *n-1* drives, parity generated and written on the remaining drive. There is no dedicated parity drive, data and parity are interleaved in all disks. In case of a disk failure, data in the failed disk is reconstructed from the remaining disks reversing the parity algorithm. It requires less disk drives than RAID-1, but there is a write penalty associated with generating parity for each record, since old data and parity must be read, new parity generated, and new data and parity written for each update. On the other hand, it allows better read performance enabling access to several disks at the same time. It is best for systems in which performance is not critical or which do few write operations.

RAID types such as 0+1 or 1+0 refer to the RAID implementation that is done first. RAID 1+0 would offer more protection than RAID 0+1.

Table 3-1 provides a summary of RAID level definitions.

Table 3-1 RAID levels definitions

RAID level	Description
RAID 0	Data striping, no fault protection.
RAID 1	Disk mirroring. Dual copy
RAID 0+1	Data striping and mirroring
RAID 2	Bit interleave with hamming code
RAID 3	Bit interleave data striping with parity disk
RAID 4	Block interleave data striping with parity disk
RAID 5	Block interleave data striping with skewed parity disk
RAID 6	Block interleave data striping with double skewed parity disk
RAID1+0(RAID10)	Data mirroring and striping

Some disk storage subsystems offer RAID protection without the need for operating system intervention. For example, the IBM Enterprise Storage Server (ESS) can be configured for RAID 5 or RAID 10 without any performance degradation, since it is controlled by the internal software.

3.6.2 Mirroring

The basic idea of mirroring is to preserve data availability by having two or more copies in different storage devices. If one device fails, the data is still available from another device.

Mirroring can be performed by hardware, like disk arrays supporting RAID-1 or ESS Peer-to-Peer Remote Copy (PPRC); by software, like AIX Logical Volume Manager Mirroring, Veritas Volume Manager, and Windows NT mirroring; or by a combination of hardware and software, like ESS Extended Remote Copy (XRC) in the OS/390® platform.

We can also differentiate between synchronous or asynchronous mirroring. In synchronous mirroring, any write must be completed on all copies before the operation is considered complete. In asynchronous mirroring, the write operation is completed in the primary device and then propagated to the copies.

Synchronous mirroring allows a quick data recovery, since both copies are exactly the same, but it has an impact in write performance, since we have to wait until write operations are performed in all devices.

Asynchronous mirroring does not have the write penalty, but in the case of a failure, we may lose the updates that are pending, so it has an impact on the time and procedures required for data recovery when needed.

The distance supported by SAN allows us to have devices further apart from each other and that way we can mirror a storage device in one site with another located in a different site. Having storage devices mirrored at different locations preserves data availability — not only in the case of disk failures, but also in case of any disaster affecting the primary site.

3.6.3 Clustering

Basically, a cluster is a group of servers that appear to clients in the network as a single entity. This group is managed as a single machine and the physical characteristics are transparent to users. Each individual server is known as a node.

The main benefits of clustering are scalability and availability. When workload increases, nodes can be added to absorb the additional workload and keep the performance levels. In the same way, if a node fails, or it is too busy, its workload can be absorbed by the remaining nodes transparently to the end users.

There are different classifications of clustering according to the way it is implemented: there are clusters implemented at a hardware level, at the operating system level, and the application level.

What all clustering solutions have in common is the requirement for shared access to storage. Here is where a SAN comes in to play, by offering the capacity of attaching different servers and different storage devices, providing the required bandwidth for concurrent access to data, and supporting the scalability requirements of adding additional servers or storage devices when required without modifying the basic infrastructure.

The Fibre Channel technology also offers the possibility of a longer distance between nodes or between nodes and storage devices.

A geographically dispersed cluster can provide a business continuity solution in case of a disaster affecting one of the sites.

3.6.4 Dual pathing

The idea of dual pathing, or multipathing in general, is to provide for a higher bandwidth so more data transfers can take place simultaneously, and also to maintain data availability in case of path failures.

Multipathing is common in the OS/390 environment, and the channel subsystem takes care of it. In the open systems environment, we get an instance of each device on each path, so the appropriate software is required to handle multipath configurations.

Since a SAN typically provides more than one path between a server and a storage device, multipathing software is mandatory.

Different vendors provide their own version of multipath software. Both Emulex and QLogic also offer multpathing with the purchase of their HBAs.

IBM has been offering the Data Path Optimizer (DPO) for AIX and Windows NT. For all ESS customers DPO has been superseded by the IBM Subsystem Device Driver (SDD).

IBM Subsystem Device Driver

The IBM Subsystem Device Driver (SDD) resides in the host server with the native disk device driver for the ESS. It uses redundant connections between the host server and disk storage in an ESS to provide enhanced performance and data availability.

The IBM Subsystem Device Driver provides the following functions:

- Enhanced data availability
- Automatic path failover and recovery to an alternate path
- Dynamic load balancing of multiple paths
- Concurrent download of licensed internal code
- Path selection policies for the AIX operating system:
  - IBM AIX
  - HP
  - Linux Red Hat and SuSE (Intel®)
  - Novell
  - Sun
  - Microsoft® Windows NT and 2000

In most cases, host servers are configured with multiple host adapters with SCSI or Fibre Channel connections to an ESS that, in turn, provides internal component redundancy. With dual clusters and multiple host interface adapters, the ESS provides more flexibility in the number of I/O paths that are available.

When there is a failure, the IBM Subsystem Device Driver reroutes I/O operations from the failed path to the remaining paths. This function eliminates the following connections as single points of failure: a bus adapter on the host server, an external SCSI cable, a fiber-connection cable, or a host interface adapter on the ESS. This automatic switching in case of failures is called path failover.

In addition, multi-path load balancing of data flow prevents a single path from becoming overloaded with I/O operations.

For the specific versions that are supported, and additional information about SDD refer to the *IBM Subsystem Device Driver Users Guide,* SC26-7478 at Web site:

```
http://ssddom02.storage.ibm.com/techsup/webnav.nsf/support/sdd
```

3.7 SAN platforms

In the topics that follow we discuss some of the platforms that are encountered in a SAN:

- zSeries® and S/390
- pSeries®
- xSeries®
- iSeries™

3.7.1 zSeries and S/390

The zSeries and S/390 platforms have a dedicated I/O subsystem that offloads workload from the processors allowing for high I/O data rates. Installations with high numbers of I/O devices and channels are very common. To solve the cabling and distance limitations of the Bus and Tag I/O connections, ESCON was introduced more than 10 years ago. ESCON, a serial interface using fiber optics as connecting media, has been delivering customers increased distance, reduced cable bulk, disk and tape pooling, clustering and data sharing, while providing management capabilities. Other vendors also supported ESCON, and it was adopted as a standard by NCITS.

FICON™ comes as an ESCON evolution. FICON is based on the Fibre Channel standard, so OS/390 and z/OS® is positioned to participate in heterogeneous Fibre Channel based SANs.

FICON support started bridging from FICON channels to existing ESCON directors and ESCON control units, delivering value using channel consolidation, cable reduction, increased distance and increased device addressability.

We are now in the next phase that includes native FICON control units, attached either point-to-point, or switched point-to-point, using FICON capable directors. Since FICON is an upper layer protocol using standard Fibre Channel transport, FICON directors are highly available Fibre Channel switches with capabilities that allow in-band management.

From an availability point of view, zSeries and S/390 offer the possibility of a Parallel Sysplex® configuration, the highest available configuration in the market. In a Parallel Sysplex, several processors are normally sharing I/O devices. ESCON directors have traditionally been used to allow sharing while reducing the number of control unit ports and the cabling requirements. With the introduction of FICON, processors and I/O can share a SAN with other platforms.

More information about Parallel Sysplex can be found at this Web site:

http://www-1.ibm.com/servers/eserver/zseries/pso/

Additional information about SAN on the zSeries and S/390 platforms, and future directions can be found at this Web site:

http://www-1.ibm.com/servers/eserver/zseries/san/

3.7.2 pSeries

There are different vendors that offer their own version of UNIX in the market. Each vendor (IBM, SUN, HP) offers its own hardware and different flavors of the UNIX operating system (AIX, Solaris, HP UX), each having some unique enhancements and often supporting different file systems (JFS, AFS®).

There are also several versions of management software available for the UNIX environment, such as Tivoli Storage Manager (TSM), and Veritas.

The IBM version of UNIX is the AIX Operating System and pSeries hardware. IBM currently offers a wide range of SAN ready pSeries servers from the entry servers up to Large Scale SP systems. Additional information regarding connecting pSeries servers to a SAN can be found in the IBM Redbook, *Practical Guide for SAN with pSeries,* SG24-6050.

More details can be found at the Web site:

http://www-1.ibm.com/servers/solutions/pseries/

3.7.3 xSeries

The platform of Intel based servers running Windows is a fast growing sector of the market. More and more of these servers will host mission critical applications that will benefit from SAN solutions such as disk and tape pooling, tape sharing, and remote copy.

IBM offerings in this platform include Netfinity®, NUMA-Q®, and xSeries. Additional information regarding connecting pSeries servers to a SAN can be found in the IBM Redpaper extract, *Implementing IBM server xSeries SANs*, REDP0416.

More details regarding xSeries can be found at the Web site:

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http://www-1.ibm.com/servers/solutions/xseries/
```

3.7.4 iSeries

The iSeries platform uses the concept of single-level storage. The iSeries storage architecture (inherited from its predecessor systems System/38™ and AS/400®) is defined by a high-level machine interface. This interface is referred to as Technology Independent Machine Interface (TIMI). It isolates applications and much of the operating system from the actual underlying systems hardware. They are also unaware of the characteristics of any storage devices on the system because of single-level storage.

The iSeries is a multi-user system. As the number of users increase, you do not need to increase the storage. Users share applications and databases on the iSeries. As far as applications on the iSeries are concerned, there is no such thing as a disk unit. The idea of applications not being aware of the underlying disk structure is similar to the SAN concept.

Additional information regarding connecting pSeries servers to a SAN can be found in the IBM Redbook, *iSeries in Storage Area Networks: Implementing Fibre Channel Disk and Tape with iSeries,* SG24-6220-00.

More details regarding iSeries can be found at the Web site:

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http://www-1.ibm.com/servers/solutions/iseries/
```

3.8 Security

Today, Fibre Channel fabrics are deployed in a variety of applications. Being developed to obtain SCSI connectivity for storage applications, Fibre Channel removes the traditional boundaries associated between SCSI devices. Storage interfaces, once propagated within the server or data center, may be extended outside the typically secure physical cabinet or location.

The Fibre Channel fabric and its components are also considered shared resources. This includes the switched fabric, the storage attached to the fabric and the services the fabric provides. This accessibility, plus the increase in both the quantity of data and users of that data, has heightened the awareness of the IT community to security exposures. As such, Fibre Channel fabrics and their components are prone to the same types of security breaches once associated mostly with IP networks.

3.8.1 Control types

Many of the security layers can be configured to ensure that only the appropriate users or systems have access to data. Determining the specific values for these different variables and then correctly implementing steps to enforce the policies can be quite challenging. The following three control types are important to creating a complimentary matrix of checks and balances to gain security in a SAN:

- **Operational controls:** Processes that are typically implemented by security personnel. These controls have to work well in conjunction with management controls and technical controls. and are defined in security documents. Refer to “Operational controls” on page 143 for more information on this type.
- **Management controls:** Procedures and policies that ensure that there is proper management oversight with regards to security.
- **Technical controls:** Security measures implemented by hardware and software. In conjunction with strong operational controls and management controls, technical controls can detect unauthorized access, track changes, implement security policies.

More information about policies can be found at the Web sites:

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http://www.sans.org/resources/policies/
http://www.aits.uillinois.edu/security/securestandards.html#introduction
```

3.8.2 Vulnerabilities

It is a matter for debate if there is such a thing as 100% security for any kind of data. You could disconnect the information database from the rest of the world and “seal” it in concrete to preserve it — but then it would be rather inaccessible and probably not of much value in such an environment. Accessibility for your business applications on SAN will be achieved by interconnection and the network. The network, being a LAN or a SAN with hundreds or more servers, storage devices, and connections, can have plenty of weaknesses in security to consider. You may reduce the possible vulnerabilities into three groups categorized by traffic type, as shown in Figure 3-13.

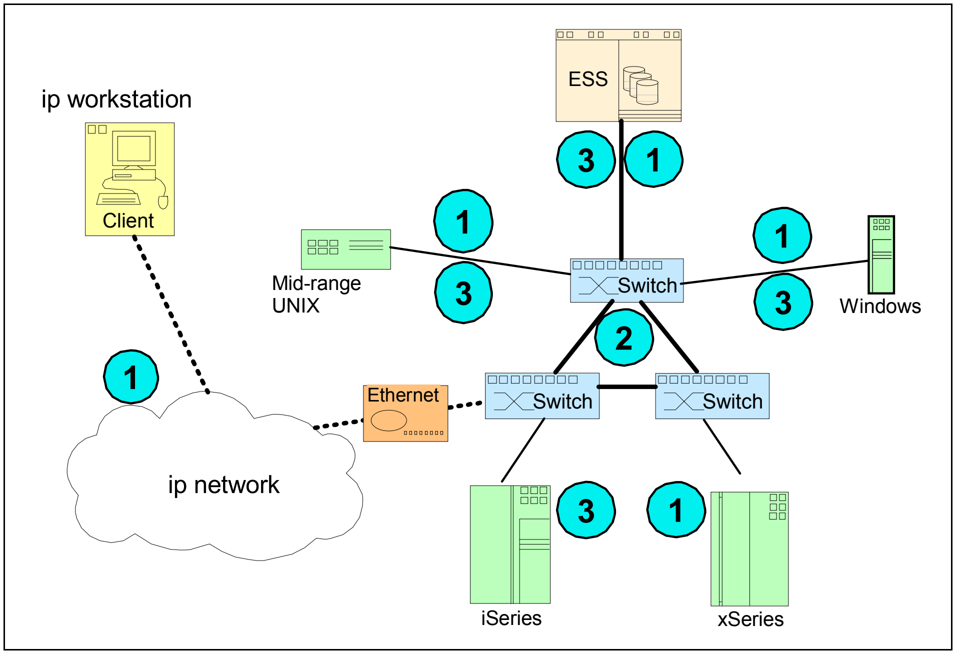

Figure 3-13 Vulnerabilities

Device-fabric traffic

This category includes any traffic that originates on servers and terminates on a fabric switch using Fibre Channel, IP, or other means. The devices can be systems that plug into the Fibre Channel ports of the SAN fabric via an HBA, as well as workstations connected through LANs and used by SAN administrators to manage the SAN. This type of risk can include traffic from unauthorized servers connected to the wrong port, invalid management device connections, and attacks such as denial of service (DOS).

Inter-switch traffic

Inter-switch traffic risks are limited to issues posed by the interconnection of SAN switches in a fabric. Inter-switch traffic includes the traffic generated when switches attempt to create E_Ports, as well as any traffic originating *and* terminating on a fabric switch. This category does not include traffic that only traverses the switches, such as data from a server to a storage device. The concern here is that if an invalid switch is plugged into an existing fabric it can cause significant disruptions, including modifications to zoning, and unauthorized access to fabric devices or resources.

Device-device traffic

This category includes risks coming from devices that do not talk directly to the switches, but instead use the fabric as the medium over which to talk to other connected devices, such as storage elements or hosts. The concerns here are unauthorized access and the possibility of a denial of service (DOS) attack.

The standard bodies are working on security enhancements to the Fibre Channel protocol. The vendors of Fibre Channel products will implement these enhancements using various products and features and adherence to FC security standards over time.

3.8.3 Fibre Channel security

Since April 2002, the ANSI T11 group has been working on FC-SP, a proposal for the development of a set of methods that allow security techniques to be implemented in a SAN.

Up until now, fabric access of Fibre Channel components was attended to by identification (**who are you?**). This information could be used later to decide if this device was allowed to attach to storage (by zoning), or it was just for the propagation of information (for example, attaching a switch to a switch) — but it was not a criteria to refuse an inter-switch connection.

As the fabric complexity increases, more stringent controls are required for guarding against malicious attacks and accidental configuration changes. Additionally, increasingly more in-fabric functionality is being proposed and implemented that requires a closer focus on security.

The customer demand for protecting the access to data within a fabric necessitates the standardization of interoperable security protocols. The security required within a Fibre Channel fabric to cope with attempted breaches of security can be grouped into four areas:

Authorization **I tell you what you’re allowed to do!**

Authentication **Tell me about yourself; I will decide if you may log in**. A digital verification of who you are, it ensures that received data is from a known and trusted source.

Data confidentiality Cryptographic protocols ensure that your data was unable to be read or otherwise utilized by any party while in transit.

Data integrity Verification that the data you sent has not been altered or tampered with in any way.

3.8.4 Security mechanisms

In the topics that follow, we overview some of the common approaches to securing data.

Encryption

in 1976, W.Diffie and M.Hellman (their initials are found in **DH**-CHAP) introduced a new method of encryption and key management. A public-key cryptosystem is a cryptographic system that uses a pair of unique keys (a public key and a private key). Each individual is assigned a pair of these keys to encrypt and decrypt information. A message encrypted by one of these keys can only be decrypted by the other key in the pair:

- The public key is available to others for use when encrypting information that will be sent to an individual. For example, people can use a person's public key to encrypt information they want to send to that person. Similarly, people can use the user's public key to decrypt information sent by that person.
- The private key is accessible only to the individual. The individual can use the private key to decrypt any messages encrypted with the public key. Similarly, the individual can use the private key to encrypt messages, so that the messages can only be decrypted with the corresponding public key.

That means: exchanging keys is no longer a security concern. *A* has a public key and a private key. *A* can send the public key to anyone else. With that public key, *B* can encrypt data to be sent to *A*. Since the data was encrypted with *A's* public key, *only A* can decrypt that data with his private key. If *A* wants to encrypt data to be sent to *B*, *A* needs *B's* public key.

If *A* wants to testify that it was the person that actually sent a document, *A* will encrypt and protect the document with his private key, while others can decrypt it using *A's* public key; they will know that in this case only *A* could have encrypted this document. Each individual involved needs their own public/private key combination.

The remaining question is: when you initially receive someone's public key for the first time, how do you know it is them? If “spoofing” someone's identity is so easy, how do you knowingly exchange public keys and how do you trust the user is who they say they are? The answer is to use a digital certificate. A digital certificate is a digital document that vouches for the identity and key ownership of an individual — it guarantees authentication and integrity.

The ability to perform switch to switch authentication in FC-SP enables a new concept in Fibre Channel: the secure fabric. Only switches that are *authorized* and properly *authenticated* are allowed to join the fabric.

Whereas, authentication in the secure fabric is twofold: the fabric wants to verify the identity of each new switch before joining the fabric, and the switch that is wanting to join the fabric wants to verify that it is connected to the right fabric. Each switch needs a list of the WWNs of the switches authorized to join the fabric, and a set of parameters that will be used to verify the identity of the other switches belonging to the fabric.

Manual configuration of such information within all the switches of the fabric is certainly possible, but not advisable in larger fabrics. And there is the need of a mechanism to manage and distribute information about authorization and authentication across the fabric.

Authorization database

The fabric authorization database is a list of the WWNs and associated information like domain-IDs of the switches that are authorized to join the fabric.

Authentication database

The fabric authentication database is a list of the set of parameters that allows the authentication of a switch within a fabric. An entry of the authentication database holds at least the switch WWN, authentication mechanism Identifier, and a list of appropriate authentication parameters.

Authentication mechanisms

In order to provide the equivalent security functions that are implemented in the LAN, the ANSI T11-group is considering a range of proposals for connection authentication and integrity which can be recognized as the FC adoption of the IP security standards. These standards propose to secure FC traffic between all FC ports and the domain controller. These are some of the methods that will be used:

- **FCPAP** refers to Secure Remote Password Protocol (SRP), RFC 2945.
- **DH-CHAP** refers to Challenge Handshake Authentication Protocol (CHAP), RFC 1994.
- **FCsec** refers to IP Security (IPsec), RFC 2406.

3.8.5 IP security

There are standards and products available originally developed for the LAN and already installed worldwide. These can easily be added into and used by SAN solutions.

Simple Network Management Protocol (SNMP) had been extended for security functions to SNMPv3. The SNMPv3 specifications were approved by the Internet Engineering Steering Group (IESG) as full Internet Standard in March 2002.

IPSec uses cryptographic techniques obtaining management data that can flow through an encrypted tunnel. Encryption makes sure that only the intended recipient can make use of it. (RFC 2401).

Other cryptographic protocols for network management are Secure Shell (SSH) and Transport Layer Security (TLS, RFC 2246). TLS was formerly known as Secure Sockets Layer (SSL). They help ensure secure remote login and other network services over insecure networks.

Remote Authentication Dial-In User Service (RADIUS) is a distributed security system developed by Lucent Technologies InterNetworking Systems. RADIUS is a common industry standard for user authentication, authorization, and accounting (RFC 2865). The RADIUS server is installed on a central computer at the customer's site. The RADIUS Network Access Server (NAS), which would be an IP-router or switch in LANs and a SAN switch in SANs, is responsible for passing user information to the RADIUS server, and then acting on the response which is returned to either permit or deny the access of a user or device.

A common method to build trusted areas in IP networks is the use of firewalls. A firewall is an agent which screens network traffic and blocks traffic it believes to be inappropriate or dangerous. You will use a firewall to filter out addresses and protocols you do not want to pass into your LAN. A firewall will protect the switches connected to the management LAN and allows only traffic from the management stations and certain protocols that you will define.

4

SAN disciplines

One of the key elements of a successful SAN installation is the physical location of the equipment and the disciplines introduced to manage those elements. Typically a new SAN installation is born based on an individual requirement at the time. The new SAN usually starts small and simple, but will grow very rapidly. Disciplines which were not an issue with the small SAN become major management problems as the SAN develops. It is very difficult to introduce standards to an established SAN, so careful consideration at the conceptual phase will be rewarded.

In this chapter we look at some of the SAN disciplines that should be considered prior to implementing a SAN, and look at the potential effects of not implementing these disciplines.

We will start from the floor up and make general observations and recommendations along the way to building the SAN. In the following sections we consider the pre-planning activity and compare the pros and cons of some of the options.

Remember, simply connecting the SAN components together is not a challenge, but development of a decent SAN design is one.

4.1 Floor plan

In comparison to a traditional open server environment based on SCSI technology, with Fibre Channel Protocol (FCP) we are no longer faced with short distance limitations and are able to spread our SAN over thousands of kilometers. This has its benefits for things like Disaster Recovery, but the more you distribute the SAN, the higher the cost and management overhead.

4.1.1 SAN inventory

Prior to establishing a floor plan, it is good practice to establish a high level inventory list of the SAN components that already exist, and those that will be added to the SAN. This list, which can include logical and physical components, can be used to plan the quantity and location of the SAN fabric cabinets and will feed into a more detailed list that will help design the SAN layout.

The list should include the following:

- Server type (vendor, machine type and model number)
- Switch/director type (vendor, machine type and model number)
- Storage type (vendor, machine type and model number)
- Fibre Channel protocols that devices support and cannot support
- Device (server, storage, SAN components) names and description
- Distances between devices (maximum and minimum)
- Location of admin consoles or management servers
- Storage partitioning
- Location of SCSI drives (no more than 25 m away)
- Fabric names
- Zone names
- IP addresses
- Naming conventions employed
- Passwords and userids
- Current cabinet address
- Operating systems, maintenance level and firmware levels
- Quantity and type of adapters installed
- List of WWNs and WWPNs
- If devices will have single or multiple attachments in the SAN
- Cabling cabinets
- Labels for cables
- Cable routing mapped
- Current connections
- Current configurations

4.1.2 Cable types and cable routing

There are a number of different types of cable that can be used when designing a SAN. The type of cable and route it will take all need consideration. The following section details various types of cable and issues related to the cable route.

Distance

The Fibre Channel cabling environment has many similarities to telco and open systems environments. The increase in flexibility and adaptability in the placement of the electronic network components is similar to the LAN/WAN environment, and a significant improvement over previous data center storage solutions.

Single-mode or multi-mode

Every data communications fiber belongs to one of two categories:

- Single-mode
- Multi-mode

In most cases, it is impossible to distinguish between single-mode and multi-mode fiber with the naked eye unless the manufacturer follows the color coding schemes specified by the FC-PH (see 2.7.2, “List of evolved Fibre Channel standards” on page 79) working subcommittee (typically orange for multi-mode and yellow for single-mode). There may be no difference in outward appearance, only in core size. Both fiber-optic types act as a transmission medium for light, but they have different diameters and different demands for the spectral width of the light sources:

- **Single-mode (SM):** This mode, also called mono-mode fiber, or single-mode fiber, allows for only one pathway, or propagation mode, of light to travel within the fiber. The core size is typically 8.3 - 10 µm. SM fibers are used in applications where low signal loss and high data rates are required, such as on long spans between two system or network devices, where repeater/amplifier spacing needs to be maximized. SM fiber links use longwave laser at 1270-1300 nm wavelength.
- **Multi-mode (MM):** This mode, also called multi-mode fiber, allows more than one mode of light. Common MM core sizes are 50 µm and 62.5 µm. MM fiber links can either use a shortwave (SW) laser operating at 780-860 nm, or a longwave (LW) laser at 13270-1300 nm wavelength. The low-cost shortwave laser is based on the laser diode developed for the CD players and benefits from the high volume production with that market. That makes shortwave/MM- equipment more economical. MM fiber is therefore the ideal choice for short distance applications between Fibre Channel devices.

For the supported distances of 1 Gb/s and 2 Gb/s links, refer to 2.2.1, “Small Form Factor Optical Transceivers” on page 21, and 2.2.2, “Gigabit Interface Converters” on page 23.

In Figure 4-1 we show the differences in single-mode and multi-mode fiber routes through the fiber-optic cable.

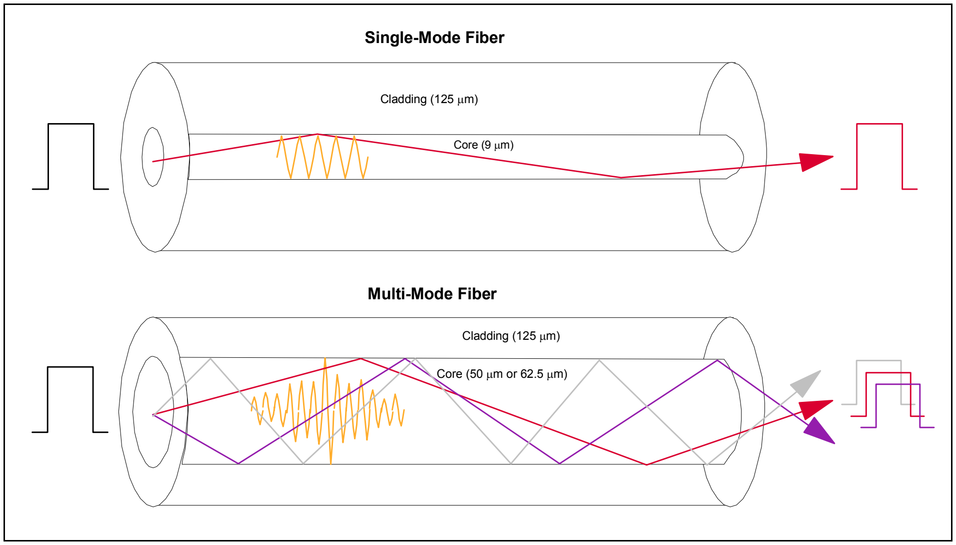

Figure 4-1 Mode differences through the fiber-optic cable

Propagation mode: The pathway of light is illustrative in defining a mode. According to electromagnetic wave theory, a mode consists of both an electric and a magnetic wave mode, which propagates through a waveguide. To transport a maximum of light, we need to have a total internal reflection on the boundary of core and cladding. With the total reflection, there comes a phase shift of the wave.

We look for modes that have the same wave amplitude and phase at each reflection to interfere constructively by wave superposition. With help of the mode equation we will find modes for a given electromagnetic wave (the light with its wavelength) propagated through a given waveguide (a fiber with its geometry). We call a waveguide *mono-mode* when only the lowest order bound mode (fundamental mode of that waveguide) can propagate.

There is exhaustive technical and scientific material about fiber and optics in ‘Optics2001.com’, the free Optical Community at the Web site:

http://www.optics2001.com/Optical-directory.php

Fiber optic cable

Fiber optic cable for telecommunications consists of three components:

- Core
- Cladding
- Coating

Core

The core is the central region of an optical fiber through which light is transmitted. In general, the telecommunications industry uses sizes from 8.3 µm to 62.5 µm. As already discussed, the standard telecommunications core sizes in use today are 8.3 (9) µm, 50 µm and 62.5 µm.

> **Note:** Microns or micrometers (µm)? A micron is 0.0000394 (approximately 1/25,000th) of an inch, or one millionth of a meter. In industrial applications, the measurement is frequently used in precision machining. In the technology arena, however, microns are most often seen as a measurement for fiber-optic cable (which has a diameter expressed in microns), and a unit of measure in the production of microchips.
>
> Micrometer is another name for a micron, but it is more commonly used for an instrument that measures microns in a wide variety of applications, from machine calibration to the apparent diameter of celestial objects.

Cladding

The diameter of the cladding surrounding each of these cores is 125 µm. Core sizes of 85 µm and 100 µm have been used in early applications, but are not typically used today. The core and cladding are manufactured together as a single piece of silica glass with slightly different compositions, and cannot be separated from one another.

Coating

The third section of an optical fiber is the outer protective coating. This coating is typically an ultraviolet (UV) light-cured acrylate applied during the manufacturing process to provide physical and environmental protection for the fiber. During the installation process, this coating is stripped away from the cladding to allow proper termination to an optical transmission system. The coating size can vary, but the standard sizes are 250 µm or 900 µm. The 250 µm coating takes less space in larger outdoor cables. The 900 µm coating is larger and more suitable for smaller indoor cables.

The 62.5 µm multi-mode fiber was included within the standard to accommodate older installations which had already implemented this type of fiber-optic cable. Due to the increased modal dispersion and the corresponding distance reduction of 62.5 µm multi-mode fiber, 50 µm multi-mode fiber is the preferred type for new installations. It is recommended to check with any SAN component vendor to see if 62.5 µm is supported.

For more details about fiber-optic cables, visit the “American National Standard for Telecommunications” Glossary at the Web site:

http://www.atis.org/tg2k/t1g2k.html

Structured and non-structured cables

In this topic we look at two types of cables: non-structured and structured.

Non-structured cables

Non-structured cables consist of a pair of optical fibers that provide two unidirectional serial bit transmission lines; they are commonly referred to as a jumper cable. Jumper cables are typically used for short links within the same room. They can be easily replaced if damaged, so they are most suited to connecting SAN components that may require regular cabling alterations.

Multi-jumper cables are available with more than one pair of fibres. They are typically used to connect more than one pair of Fibre Channel ports.

As individual cables can become easily tangled and difficult to locate, they are best avoided for longer under-floor runs.

Structured cables

Structured cables consist of multiple fiber optic cables wrapped as a single cable that have a protective member and outside jacket, and these cables are commonly referred to as trunk cables. Trunk cables are normally terminated at each end into the bottom of a patch panel. Jumper cables are then used from the top of the patch panel to the SAN fabric.

Typically trunk cables are used for longer runs between server and SAN fabric cabinets, as the trunk cable terminates at a patch panel, normally there is no requirement to make future cable alterations.

In Table 4-1 we compare the advantages and disadvantages of using non-structured and structured cabling practices for server cabinet to SAN fabric cabinet connections.

Table 4-1 Comparison between structured and non-structured cables

Non-structured cables	Structured cables
Unknown cable routing	Known cable route
No cable documentation system	Defined cable documentation
Unpredictable impact of moves, adds and changes	Reliable outcome of moves, adds and changes
Every under floor activity is a risk	Under floor activity can be planned to minimize risk
No waste, only the cables required are run	Initially not all fibers will be used; spare cables will be run for growth

There are a number of companies that provide fiber cabling service options. IBM provide this service offering with Fibre Transport Service Cabling System (FTS).

When planning the use of trunk cable over a longer distance it is important to consider the potential light loss. Every time a joint is made in a fiber cable there will be a slight light loss, with the termination at the patch panel there will be considerably more light loss.

The fibre installation provider should be able to calculate potential light loss to ensure the trunk cable run is within acceptable light loss limits.

Patch panels

Patch panels are commonly used to connect trunk cables, particularly between floors and buildings. They provide the flexibility to enable repatching of fibres but generally the panel configuration will remain the same after installation. Pay attention not to mix fibre cables with different diameters when crossing patch panels.

4.1.3 Planning considerations and recommendations

Many miscellaneous considerations are needed to successfully install fiber-optic links for any protocol. However, the higher data rate and lower optical link budgets of Fibre Channel lends itself to more conservative approaches to link design. Some of the key elements to consider are:

- All links must use the currently predominant “physical contact” connectors for smaller losses, better back reflectance, and more repeatable performance.
- The use of either fusion or mechanical splices is left to the designer to determine the desired losses weighed against the cost of installation.

- Multi-mode links cannot contain mixed fiber diameters (62.5 and 50 micron) in the same link. The losses due to the mismatch may be as much as 4.8 dB with a variance of 0.12 dB. This would more than exceed the small power budgets available by this standard.
- The use of high quality factory terminated jumper cables is also recommended to ensure consistent performance and loss characteristics throughout the installation.
- The use of a structured cabling system is strongly recommended even for small installations.
- A structured cabling system provides a protected solution that serves current requirements as well as allows for easy expansion.
- The designer of a structured system should consider component variance affects on the link if applicable.

Much of the discussion so far has been centered around single floor or single room installation. Unlike earlier FDDI or ESCON installations that had sufficient multi-mode link budgets to span significant distances, Fibre Channel multi-mode solutions for the most part do not. Though the Fibre Channel standard allows for extend distance links and handles distance timing issues in the protocol the link budgets are the limiting factor.

Therefore, installations that need to span between floors or buildings will need any proposed link to be evaluated for its link budget closely. Degradation over time, environmental effects on cables run in unconditioned spaces, as well as variations introduced by multiple installers need to be closely scrutinized. The choice between single-mode and multi-mode devices may need to be made for many more links. Repeating the signal may also provide a cost effective solution if intermediary conditioned space can be found.

Since Fibre Channel provides a built in mirroring capability to SAN, in addition to its 10 km link distances using single-mode fiber, there will be more consideration for off-campus or across city links. In these cases, right-of-way issues, leasing of “dark” fiber (no powered devices provided by the lessors) issues, service level agreements, and other factors associated with leaving the client owned premises needs to be planned for and negotiated with local providers. The industry has also announced interest in providing wide area network (WAN) interfaces similar to those employed in the networking world of today. When these devices are made available, then connections to these devices will need to be included in the designs as well.

4.1.4 Structured cabling

Because of access to the Internet, the data centers of today are changing rapidly. Both e-business and e-commerce are placing increasing demands on access to and reliance on the data center. No longer is the data center insulated from the rest of the company and just used to perform batch processing.

Now, access and processing is a 24x7 necessity for both the company and its customers. The cabling that connects servers to the data storage devices has become a vital part of corporate success. Few companies can function without a computer installation supported by an efficiently structured and managed cabling system.

There are many important factors to consider when planning and implementing a computer data center. Often, the actual physical cabling is not given enough planning and is considered only when the equipment arrives. The result of this poor planning is cabling that is hard to manage when it comes to future moves, adds, and changes due to equipment growth and changes.

Planning a manageable cabling system requires knowledge about the equipment being connected, the floor layout of the data center(s), and, most importantly, how the system requirements will change. Questions that should be considered include:

- Will the data center grow every year?
- Will you need to move the equipment around the floor(s)?
- Will you upgrade the equipment?
- Will you add new equipment?
- What type of cabling do you require?
- How will you run the cables?
- How will you label the cables?
- Can you easily trace the cables if there is a problem?

Answers to these important questions should be obtained as part of the early planning for the cabling installation.

4.1.5 Data center fiber cabling options

The most prevalent data center connectivity environment that uses fiber cabling is IBM's ESCON architecture. However, the same structured fiber cabling principles can be applied in the SAN environment, and to other fiber connectivity environments such as IBM's Fiber Connection (FICON), Parallel Sysplex, and Open Systems Adapters (OSA). The examples throughout this chapter apply to structured fiber optic cabling systems designed to support multiple fiber-optic connectivity environments.

The need for data center fiber cabling implementation arises from the following three scenarios:

- Establishing a new data center
- Upgrading an existing data center by replacing the cabling
- Adding new equipment to an existing data center

IBM can help you design and implement a network that leverages existing investments, avoids costly downtime, and saves time and money when moving to performance enhancing technologies.

IBM Network Integration and Deployment Services

IBM Network Integration and Deployment Services helps businesses integrate and deploy a complex network infrastructure that leverages multivendor technologies. IBM will analyze existing networks, protocols, wired and wireless configurations to identify performance, interoperability, and connectivity requirements. Implementation planning, detailed logical and physical network design, rapid deployment and network rollouts, product installation and customization and operational services for network and cabling infrastructures is provided.

This enables business to securely converge data, voice, and video networks, enables intelligent network infrastructures, and deploy mobility solutions by exploiting technologies such as virtual private networking (VPN), video and voice over IP (VoIP), fiber optic networking, content delivery networks, storage networking and wireless.

More information is available at Web site:

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http://www-1.ibm.com/services/networking/integration/index.html
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IBM Cabling Services and the Advanced Connectivity System

Today's telecommunications infrastructure, both copper and optical fiber, supports data rates that were undreamed of even a decade ago. The cabling infrastructure is at the core of every voice, data and multimedia network.

Integrating multivendor equipment has become challenging, time-consuming and increasingly dependent on how IT systems are physically connected. Proper planning, configuration and installation for connectivity is critical. Our professionals can analyze your existing network, protocols, wiring configurations and cabling infrastructure, identify system interoperability and connectivity requirements, and help you connect and integrate your cabling systems.

IBM has a wide array of premises, data center, server and storage networking solutions to help select and install the right cabling solution for the e-business infrastructure.

Cabling solutions using the IBM Advanced Connectivity System include copper and fiber solutions for any building or premises, and each is designed to be intermixed and adapted to different topologies. There is a choice of several grades of cabling infrastructures that meet or significantly exceed today's technical standards and performance demands.

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http://www-1.ibm.com/services/networking/integration/acs.html
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Metropolitan Area Network cables

Metropolitan Area Network (MAN) cables are typically used for business continuance between two sites. MANs used for business continuance normally consist of a diverse route of a primary and alternate cable. The alternate route is normally only used when the primary route is not available. To ensure we introduce no single points of failure it is critical these cables enter and leave the building at separate locations and at no point share the same cable run or equipment.

It is important to have a detailed intersite cable route plan to highlight any single points of failure and to determine the exact distance of both routes.

If the primary site is several kilometers shorter than the secondary route, there may be latency issues to consider when using the secondary route. It will only introduce problems, when there is parallel MAN links used in a shared manner, and the skew which comes with the different latencies cannot be handled by the protocol.

As the MAN cables enter the buildings, the routes of the primary and alternate cables should be clearly marked on the floor plan.

Ethernet cables

The majority of SAN products require IP addresses to enable remote software management. To ease the administration of SAN management it is common to place the Ethernet ports within the same LAN or VLAN and choose IP addresses from the same IP subnet.

Ethernet cables will need to be laid from the site Ethernet switch to the SAN fabric cabinet, and these cable routes should be detailed on the plan.

Future growth

Future technologies and design issues are mostly affected by length and attenuation due to increased speeds. Since future technologies are unknown, most organizations are pulling single-mode fiber along with the new multi-mode fiber while keeping the proposed distance limitations in mind when designing the cable plant.

One option is to leave the single-mode fiber un-terminated and dark for future technologies. Connectors, panels, and the labor to terminate, test, and install these items could be a significant cost, so leaving these cables un-terminated and dark can save money in the short term.

Another option is to proceed with the termination in anticipation of rapid technological developments. Indications point to a reduction in the cost of LW lasers. This would drive down the price of LW technology and LW equipment applications, influencing the adoption of single-mode usage as well.

4.1.6 Cabinets

For IBM SAN fabric components that do not come with an associated cabinet, you will have a choice of rack mount or non-rack mount feature codes. In most cases it is advisable to select the rack mount option for the following reasons.

- **Security:** To prevent unauthorized actions on the SAN fabric components, the cabinet can be locked and key access restricted to selected personnel.
- **Audit trail:** Hardware changes can be tracked by recording who has requested the cabinet key, and at what time.
- **Cable Management:** When there are large numbers of fibre cables hanging from the SAN fabric, it can be very difficult to locate and alter cables. You also have an associated risk that when you are making SAN cable alterations, you may damage other cables in the SAN fabric. The use of cable supports, cable ties or velcro strips will enable cables to be tied back along the cabinet edges, reducing the risk of accidently damage and enabling cables to be easily identified.
- **Hardware replacement:** When customer engineers need to repair or replace a part of the SAN fabric, it is important they have easy access to the component. The use of racks will guarantee they are able to access the device without disturbing any other SAN components.
- **Power outlets:** Most cabinets have a default number of power outlets, this number can be used to plan current and future SAN fabric power requirements.
- **Component location:** Each cabinet should be clearly labelled, these labels can be incorporated within the SAN fabric components naming standards. In the event of a problem or change the correct component can be easily identified.

In Figure 4-2 we show an example of a SAN fabric that has not been racked, and where only one cable has been labelled. It is easy to see how cables could become damaged and mistakes could occur.

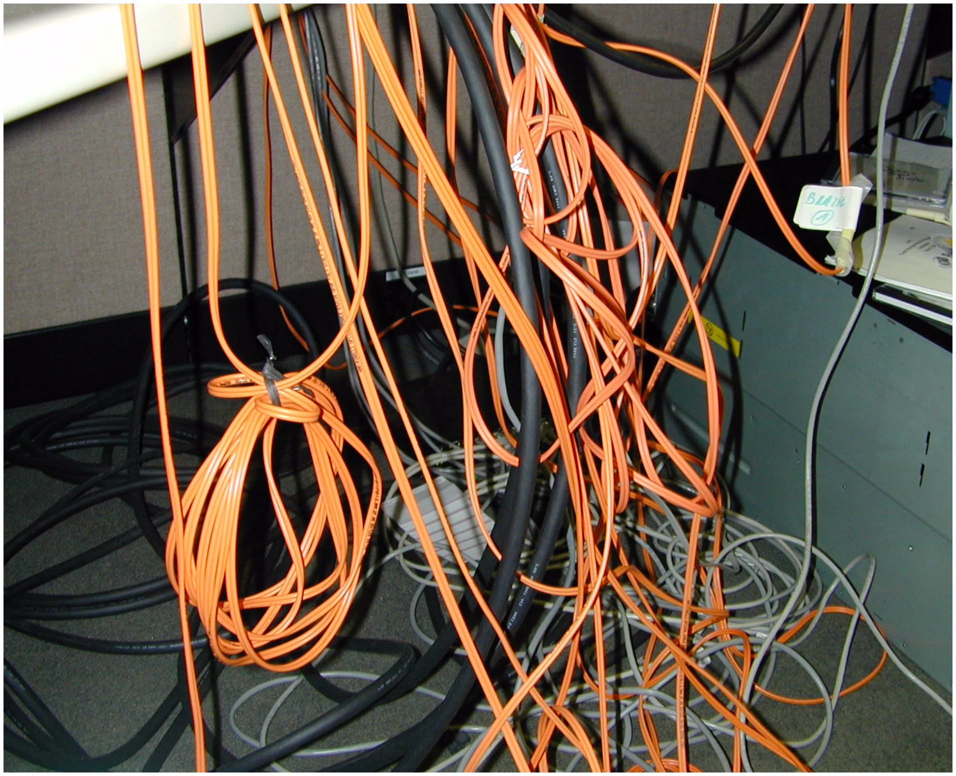


Figure 4-2 Messy cabling, no cabinet, and no cable labels

4.1.7 Phone sockets

Most of the larger SAN devices will have dial home facilities which will require a phone line. Although phone lines can be shared between devices, sufficient phone sockets need to be provided to prevent phone line bottlenecks. It is also wise to think about ensuring that spare phone lines are available should one fail, or be in use for a long period of time for any reason.

As an example, if a phone line was shared between an IBM ESS and a fabric component, and if log information had to be extracted from the ESS, the phone line could be busy for over one hour — and any potential error on the fabric component may go unnoticed.

4.1.8 Environmental considerations

In this section we consider some basic requirements for power sources and heat dissipation.

Power

The majority of SAN components have the option of single or dual power supplies. To realize the benefits of two power supplies, it is essential the power source supplying the devices is from two independent supplies.

In a cabinet full of smaller SAN fabric devices with dual power supplies, it is very easy to exceed the available number of power sockets.

You need to ensure the SAN fabric cabinet has sufficient power sockets to satisfy the SAN fabrics power requirement from both day one and a potentially full cabinet.

Heat

Several small switches in a SAN cabinet will generate quite a lot of heat. To avoid heat damage it is important the cabinet is located in a room that has temperature control facilities.

4.1.9 Location

Typically the location of the SAN fabric cabinets, servers and storage (disk and tape) will be dictated by available space and power supply.

The typical placement for components is in clusters around the periphery of the work area. This minimizes the length of cables and their exposure to points of failure. An alternative is to locate components in a central cluster. However, the smaller the area that the components are gathered in, the more potential exists for a burst pipe, for example, taking out the whole fabric. It may be wise to distance some components apart from each other.

The further that the two components are apart, the less likely it is that a single disaster will render both of them unusable.

4.1.10 Sequence for design

Assuming you are cabling a facility with existing components, the usual sequence is to do the following:

- Base it on the server inventory and detail the current components accurately and completely.
- Determine what new components will be added and their location.
- Verify that the type of cable is appropriate for each connection.
- Calculate loss and attenuation for each connection and for the total system.
- Modify the design as needed.

A detailed floorplan should be drawn with cabinet and slot locations of all components of the SAN. The floorplan should include:

- Servers
- SAN fabric
- Storage devices
- Cable routes
- Cable type
- Cable entry and exit points
- Power points
- Power source
- Phone lines
- Ethernet cable routes
- Location of SAN ethernet hub and any required ethernet switches

If two buildings are connected using a MAN or similar, the cable routes, the total distance of both the primary and secondary routes, and the entry and exit points into the building need to be detailed.

On completion of the floor plan, the checklist displayed in Table 4-2 in should be performed to validate the proposed layout.

Table 4-2 Checklist for proposed layout

Check	Validate	Successful
Location of SCSI devices	Within 25 m of SAN bridge device	
Multi-mode, shortwave devices	Within 550 m (1 Gb/s) and 300 m (2 Gb/s)	
	Cable route uses 50/125 multi-mode fiber	
Single-mode, shortwave devices	Within 275 m (1 Gb/s) and 150 m (2 Gb/s)	
	Cable route uses 62.5/125 multi-mode fiber	
Long-wave devices no extender	Within 10 km	
Long-wave devices with extenders	Within 100 km	
Power source	Independent supply	

Check	Validate	Successful
Number of power sockets	Sufficient number, including units with dual power supply	
Location of SAN devices	In a lockable cabinet	
	Sufficient space in SAN cabinets	
LAN	Sufficient free IP addresses and Ethernet ports for SAN devices	
Capacity	No physical constraints for growth - cables, full cabinets, and so on	
Phone sockets	Location and quantity of phone sockets that require dial home	

4.2 Naming conventions

Use of descriptive naming conventions is one of the most important factors in a successful SAN. Good naming standards will improve problem diagnostics, reduce human error, allow for the creation of detailed documentation and reduce the dependency on individuals.

4.2.1 Servers

Typically, servers will already have some form of naming standard in place.
If a server name does exist, it should have been captured during inventory, as described in 4.1.1, “SAN inventory” on page 124.

The local server name is typically used as the host name defined to the disk system. For the ESS you would normally use the server name in the server description field. The same local server name can be used within the switched fabric as an alias for zone settings, and whenever possible the use of the server name should be consistent throughout the SAN.

4.2.2 Cabinets

SAN fabric cabinets should be labelled to adhere with local site standards.

4.2.3 SAN fabric components

A good naming convention for the SAN fabric component should be able to tell you the physical location, component type, have a unique identifier and give a description of what it connects to. The following are some descriptor fields that may be considered when designing a fabric naming convention. If your SAN only has one vendor type or only one cabinet the name could be a lot simpler.

Component description

This should describe the fabric component and the product vendor (for mixed vendor environments) which will help you locate the management interface and the component number within the SAN. For example, to give it a unique identifier you may want to use something similar to the following:

- Type — Switch (S) Director (D) Gateway (G) Hub (H) Router (R)
- Vendor — Brocade (B) CNT (I) McDATA (M) Vicom (V)
- Number — 1 - 99

For example, the third Brocade Switch in cabinet one would be:

- S3 B

Connection description

This should detail what the component is connecting to. For highly available devices such as the ESS, it is important to understand which cluster side of the device the component is connected to. This will help prevent potential mistakes in the SAN design. For devices used to expand the SAN that do not connect to disk or tape, we will simply identify them as cascade.

- Connection — Disk (D (for ESS either cluster A or B)), Tape (T), Cascade (C)
- Number — 1 - 99

To continue our example, the third Brocade Switch in cabinet one connecting to ESS3 Cluster A would be

- S3 B D3A

Physical location

This may be the cabinet descriptor field and, for example, SAN cabinet one could be C1. For our example this would give us:

- S3 B D3A C1

We show how our name is developed in Figure 4-3.

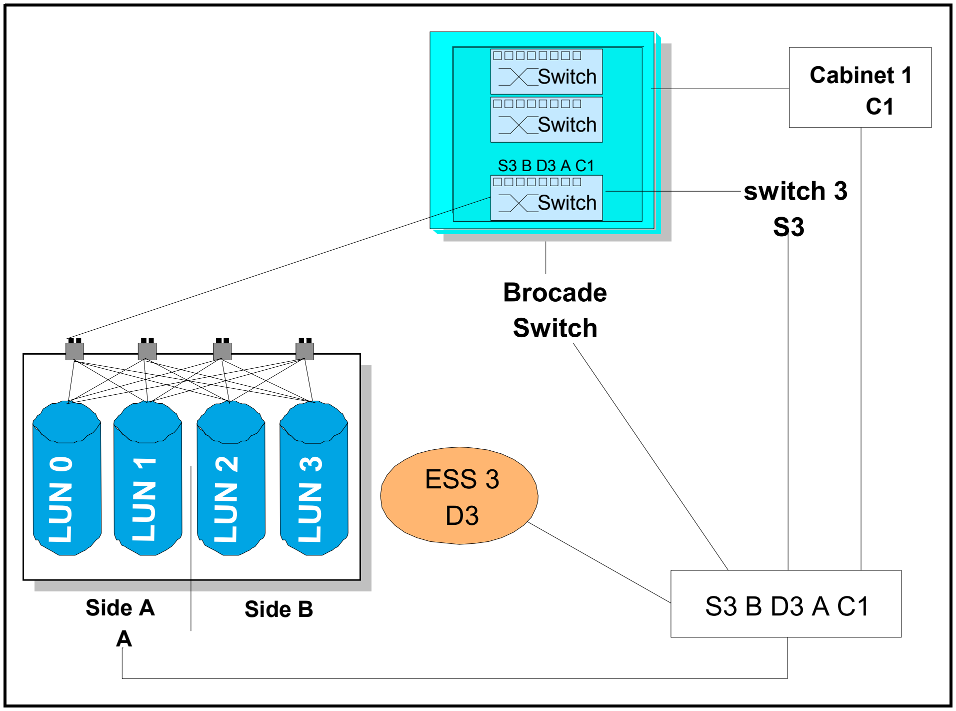


Figure 4-3 Naming convention development

4.2.4 Cables

Modifications to a SAN that does not have sufficient labelling in place could lead to the incorrect selection and reconfiguration of the SAN with potentially disastrous effects.

When determining the exact cable identification tag, try to avoid using device specific names. Such names do not take into account adding or subtracting devices, or devices being renamed, which are fundamental parts of a SAN.

The chosen cable tag naming standard should be incorporated in a detailed SAN fabric port layout plan. The port layout plan will enable you to identify the exact devices to which the cable is connected.

Any SAN cable reconfigurations should have an associated change record. Part of that change process should include a pointer to update the cable tag and port layout plan. Adhering to this plan will ensure that the document is always kept up-to-date.

4.2.5 Zones

Understanding software zones defined by another SAN administrator, when no naming standards have been defined, can be very difficult. Researching the zone setting can be time consuming and can cause problems if activated incorrectly. The introduction of site standard software zone naming standards will minimize this risk.

A good zone naming standard should consist of a meaningful description of the servers effected by the zone and what you are hoping to achieve.

For example, if we assume that the WWNs of servers ABC_FIN1 and ABC_FIN2 (the company production finance server) have been zoned to only see the WWN of disk ESS3.

If we called this zone1, the creator would probably understand what the zone was doing. If, at a later stage, the finance department requested the ability to access archive files that resided on ESS1, a modification to zone1 would be required. However, as zone1 gives us no descriptive information as to the contents of the zone itself, for anyone other than its creator, this change would be very difficult and may involve investigating every zone to see its contents.

If, however, we had called the zone PRODFINESS3, locating and modifying the zone would be much simpler.

4.3 Documentation

There are a number of software tools (such as Tivoli's TSNM) that are able to provide detailed information and documentation about the SAN. This includes connection diagrams, server utilization reports and status monitors and more besides.

These products, although very good at giving you an overall picture of the SAN, do not have sufficient detail to be the only source of information in order to manage the SAN.

Data that needs to be collected and recorded in SAN documents include the following:

- **Floorplan:** The floor plans of all SAN machine rooms
- **Server Inventory:** A list of servers connected to the SAN, type of Host Bus Adapters (HBAs), World Wide Name of HBAs
- **List of fabric components:** The naming convention and list of all fabric components

- **Space allocated:** A list of LUNs allocated to servers
- **Space available:** A list of free space in the disk device
- **Fabric Connection:** A detailed wiring diagram of the SAN fabric
- **Fabric Port layout:** A port usage plan detailing what ports are currently used, which ports are spare
- **Zone Information:** Both hard and soft zoning in place
- **IP addresses:** A list of IP addresses for all fabric components, as well as a list of spare ones
- **Fabric model Serial numbers:** The IBM product serial numbers (used when raising a call with the IBM call center).
- **Micro code versions:** The level of micro code installed on the disk devices (used when raising a call with IBM call center)
- **Firmware version:** The level of firmware running on the SAN fabric (used when raising a call with IBM call center)
- **Procedures:** A step-by-step how to perform a SAN function guide

In addition to the information documented for the primary site there will also be a requirement for a similar level of documentation for the disaster site.

4.4 Power-on sequence

After a site power-down, it is important to stagger the power-up of the servers connected to the SAN fabric. The reason for this is that during boot-up some operating systems will scan all the switch ports and will look up other HBA ports.

With some combinations of HBA cards this can have an adverse effect on other servers in the SAN. Symptoms can be unpredictable, ranging from clusters being brought down, to NT losing SAN access and requiring a reboot.

The use of soft zoning to separate vendor cards would prevent the risk of this occurring.

4.5 Security

Consolidating storage onto central devices has many benefits, but can also increase the risks to your business. With large amounts of critical data in one location, it is important to ensure that you are providing the maximum protection of your data. That topic was discussed from a general point of view in 3.8, “Security” on page 115.

4.5.1 General

All SAN software management tools come with a default userid and password which typically has the highest level of authority. Obtaining unauthorized access to these IDs would enable a user to alter zone information and give servers access to data that would otherwise be protected.

Generally, SAN software products do not police their userids and passwords and will not request them to be changed. It is common to find default IDs remaining on the system months after the SAN has been installed. The userids and passwords need to be changed as part of the installation, and passwords should be altered at regular intervals from then on.

Operational controls

In 3.8.1, “Control types” on page 116, operational controls were described as part of a whole security concept. Numerous attempts are required to structure and define single steps and tasks in order to archive the highest possible security level in the IT environment. Such tasks as backup and recovery, physical security, and so on, are defined in policies and grouped in operational controls.

The Acceptable Use Policy defines acceptable use of equipment and computing services, and the appropriate employee security measures to protect the organization’s corporate resources and proprietary information.

A security policy can start simply as an Acceptable Use Policy for network resources, and may grow to large documents as a complete set of laws, rules, and practices that regulate how an organization manages, protects, and distributes sensitive information. In such a policy, you can state which administration group will have access to which components: Does your SAN administration manage your servers too? (see 7.1, “Overview” on page 244 about that topic). By building up your security policy, you will define and publish your security rules. RFC 2196 suitably defines a security policy in a 73-page *Site Security Handbook*.

> **RFC 2196:** “A security policy is a formal statement of the rules by which people who are given access to an organization's technology and information assets must abide.”

The full text of RFC 2196 is available under this URL:

`http://www.ietf.org/rfc/rfc2196.txt`

4.5.2 Physical access

Physical security is an absolutely essential component of any comprehensive security plan. Even with excellent software controls in place, physical access to enterprise elements opens the door to a whole range of security issues. To ensure physical security, fabric devices should reside in environments where physical access controls provide adequate protection.

Secure machine room

With the flexibility of a SAN there is the temptation to distribute the SAN fabric in the location of the servers. This should be avoided if the locations cannot be adequately protected.

Cabinet protection

As detailed in 4.1.6, "Cabinets" on page 134, fabric cabinets should be lockable with restricted access to the key.

Switch protection

SAN switches usually provide RS-232 and Ethernet connections. Access to either of these interfaces must only be given to trusted persons, as all of the vital data of switches and fabric can be monitored and changed from here.

Cable protection

Damage to a fiber optic cable can result in performance degradation or a complete loss of access to the data. Fibers should be laid in cable trays or trunks with rodent control measures in place.

4.5.3 Remote access

There are a variety of ways to obtain information from fabric switches. Common management access methods involve the use of telnet for command line functionality, HTTP for Web-based access, in-band Fiber Channel for management server access, and console access for direct switch connectivity. Common to all of these applications is that they need IP connectivity — and the IT community has been alarmed for years about how many ways there are to break into IP hosts. Each of the possible access methods has its associated security issues.

Telnet: The essential problem with telnet access is that it transmits unencrypted the username, password, and all data going between the management system and the switch. Any user with a promiscuous network interface card and data-sniffing programs can capture the whole data transfer back and forth, including account and password.

HTTP: Similar to the telnet issues mentioned above, when a system uses a Web-based application like Web Tools to logon (authenticate) to the switch in order to run privileged commands, it passes the login information not encrypted.

Management Server: This remote management method uses an in-band Fibre Channel connection to administer or obtain information from the fabric switches. By default, it grants access to any device. However, it is possible to create an access control list to limit the WWNs of devices that can connect to the switch using this method.

Console Access: Although not usually thought of for remote access, it is possible to adapt console connections to remote use through the use of terminal server devices. Thus, an organization can use telnet, secure shell (SSH), or some similar application to connect to the terminal server, which then in turn connects to the selected device through the console interface. This solution has the potential to provide additional security through the use of third-party products.

You'll find customers who lack a firm security policy and so leave userids and passwords as default, and apply public network addresses to their switches — and then there is the other extreme: customers who disconnect the switches from the IP network. To satisfy the needs of security *and* manageability, a SAN needs the IP-connectivity *and* the strongest possible security features available.

4.6 Education

It is important that the educational requirements of all those involved in implementing and maintaining the SAN are considered in order to gain the maximum benefit from the SAN — and minimize the room of remaining human error. Therefore, the right skills have to be defined and a way to validate these skills.

4.6.1 SAN administrators

The SAN administrator is commonly responsible for effective utilization of the SAN resource, resource protection, balancing traffic, performance monitoring, utilization trending, and error diagnostics, in addition to many maintenance functions. The SAN administrator must be identified as the focal point for any additions, deletions or modifications of the SAN environment.

Management of the SAN is usually performed using the software interface that comes with each of the SAN fabric components. There are a number of software products that enable all components of the SAN to be monitored and managed from a central point. Most SAN software management tools have facilities to create different levels of access and these range from view through to full administration.

4.6.2 Skills

As already stated in 3.8, "Security" on page 115, the Fibre Channel fabric and its components are considered shared resources. This accessibility, plus the increase in both quantity of data and users of that data, has heightened the awareness of the IT community to security exposures. As such, Fibre Channel fabrics and their components are prone to the same types of security breaches once associated only with IP networks. These concerns of the SAN community reflect the same concerns of the IT community.

But not only is security a major link between SANs and LANs — the nature of connectivity is the same and it is likely to become even closer as technology matures.

Good networking skills are needed to implement and operate SANs — the kind of skills which have typically been developed in LAN environments. Good operating system and diverse platform skills are also required with this increase in connectivity — so both mainframe and open systems skills may now be needed in the same person.

The SCSI heritage in the SAN is enormous. Good storage skills must not be overlooked. The combination for SAN success in implementation and services will likely be a merged skill of networking, storage, system, and security skills.

4.6.3 Certification

Although not a part of education, certification is a good indicator as to the core competency and ability of an individual. There are a number of programs available.

IBM Professional Certification Program

The IBM Professional Certification Program is designed to validate technical skills to network administrators and integrators, systems integrators, solution architects and developers, resellers, technical coordinators, sales representative, or educational trainers.

The Program has developed certification role names to guide the participants in their professional development. The certification role names include IBM Certified Specialist, IBM Certified Solutions/Systems Expert, and IBM Certified Advanced Technical Expert for technical professionals who sell, service, and support IBM solutions. For technical professionals in application development, the certification roles include IBM Certified Developer Associate and IBM Certified Developer. IBM Certified Instructor certifies the professional instructor.

The Professional Certification Program from IBM provides with a structured program leading to an internationally recognized qualification.

Among other programs such as AIX, Linux, DB2®, WebSphere®, Lotus®, and Tivoli, IBM Professional Certification Program provides SAN certifications by offering Enterprise Tape and Disk Solutions, Open Systems Storage, and as a pure SAN certification: TotalStorage Networking Solutions.

IBM TotalStorage Networking Solutions

The IBM Certified Specialist designs IBM TotalStorage end-to-end storage networking solutions to meet customer needs. This individual provides comprehensive storage networking solutions that include servers, storage networking, storage devices, management software, and services. This specialist has detailed knowledge of SAN, NAS, and iSCSI technologies and the corresponding management software. He or she has broad knowledge of IBM storage products and their features and functions, and can describe in detail the storage networking strategy and solutions, industry, competition, and business trends.

To learn more about the IBM Professional Certification Program, visit the Web site:

http://www-1.ibm.com/certify/index.shtml

SNIA Storage Networking Certification Program

The Storage Networking Industry Association (SNIA) is introducing the industry's first vendor-independent certification program for storage networking called SNCP. The program was developed in response to demand from enterprise customers worldwide in order to provide standards for measuring the storage networking expertise of IT professionals.

The SNIA is identifying the technologies that are integral for IT professionals to understand and deploy storage networks. The first modules of the SNIA SNCP, developed for the SNIA by the industry-leading training company Infinity I/O, include certification exams testing candidates' knowledge of Fibre Channel SANs. Future modules of the SNIA SNCP are expected to include storage networking topics such as NAS and IP Storage, as well as applications such as backup and restore and capacity planning.

SNCP currently offers three levels of certification:

- Level 1 - Fibre Channel Storage Networking Professional
- Level 2 - Fibre Channel Storage Networking Practitioner
- Level 3 - Fibre Channel Storage Networking Specialist

To learn more about SNCP and the depth of the different certification levels, visit the Web site:

http://www.snia.org/education/certification/

5

Host Bus Adapters

The IBM supported SAN environments contain a growing selection of server Fibre Channel Host Bus Adapters (HBAs), each with their own functions and features. For the majority of open systems platforms, this presents us with the opportunity to select the most suitable card to meet the requirements of the SAN design.

In this chapter we provide an overview of the IBM supported HBAs and highlight any unique functions the particular card may have.

Note: For some open systems platforms, the supported HBA is actually provided by the vendor. In most cases the HBAs used by the vendor are manufactured by one of the main HBA providers detailed in this section.
For example, the HBA FC 6227 supported for pSeries servers is supplied by Emulex.

Nevertheless, this chapter can offer some value to readers of these platforms, as we provide an overview of each HBA and give detailed error diagnostic tips that would still apply to these platforms.

5.1 Selection criterion

In this section we look at a number of points that should be considered when selecting the right HBA to meet your requirements.

5.1.1 IBM supported HBAs

The first and most important factor to consider, when selecting a Fibre Channel HBA, is whether it is supported by IBM for the server make and model, and also the manner in which you intend to implement the server. For example, an HBA may be supported for the required server, but if you require dual pathing or the server to be clustered, the same HBA may no longer be supported.

To ensure that the HBA is supported by IBM in the configuration you require, refer to:

`http://www.storage.ibm.com/disk/ess/supserver.htm`

For IBMers only, for an HBA that is not detailed as supported for a specific platform, support can be requested using the Request Product Quotation (RPQ) process.

5.1.2 IBM SSG HBA and SAN interoperability matrix

For a list of the currently supported IBM SAN and storage components, refer to the Web site:

`http://ssddom02.storage.ibm.com/hba/hba_support.pdf`

5.1.3 ESS host systems attachment

For detailed instructions of how to connect HBAs to the ESS, refer to the manual:

- *IBM Enterprise Storage Server Host Systems Attachment Guide, 2105 Models E10, E20, F10 and F20*, SC26-7296

5.1.4 Special features

Any special functions you require from your SAN need to be considered, as not all HBAs may support the function. These functions could include:

- Dual connection
- Performing an external server boot
- Connection to mixed storage vendors
- Fault diagnostics

5.1.5 Quantity of servers

Another factor to consider is the number of servers in your environment that will require Fibre Channel HBAs. Having a common set of HBAs throughout your SAN environment has a number of advantages:

- It is easier to maintain the same level of firmware for all HBAs.
- The process for downloading and updating firmware will be consistent.
- Firmware and device driver can be a site standard.
- Any special BIOS settings can be a site standard.
- Fault diagnostics will be consistent.
- Error support will be from a single vendor.

5.1.6 Product specifics

In the topics that follow, we look at three vendors that are associated with the IBM portfolio of HBAs.

5.2 Emulex

At the time of writing, IBM currently supports the Emulex LP8000, LP8000S, LP9002DC, LP9002L, and LP9002S Fibre Channel adapters. Refer to the HBA interoperability matrix to find the version that is supported for your operating system at the Web site:

http://www.emulex.com/ts/docoem/framibm.htm

5.2.1 LP7000E

The Light Pulse LP7000E, a second generation Fibre Channel PCI host bus adapter, uses the Emulex Superfly chipset, a 266 MIPS onboard processor and high speed buffer memory. The LP7000E features a 32–bit PCI interface.

The 32-Bit memory acts as a frame buffer and enables the LP7000 to achieve its high performance throughput.

The 1 Gb/s LP7000E provides features, including switched fabric support using F_Port and FL_Port connections, full-duplex data transfers, high data integrity features, support for all Fibre Channel topologies, and support for service classes 2 and 3.

5.2.2 LP8000

In Figure 5-1 we show the third generation Fibre Channel PCI host bus adapter, the LP8000 which uses the Dragonfly ASIC with a 266 MIPs onboard processor and offers 128 KB buffer RAM. It supports simultaneous full duplex 1 Gb/s, which delivers up to 200 MB/s.

Similar to the 64 buffer credit associated with a longwave port in a switch or director, the 64 Bit interface enables the LP8000 to sustain high performance over a distance of up to 10 km. This buffer capability improves the performance of the card.

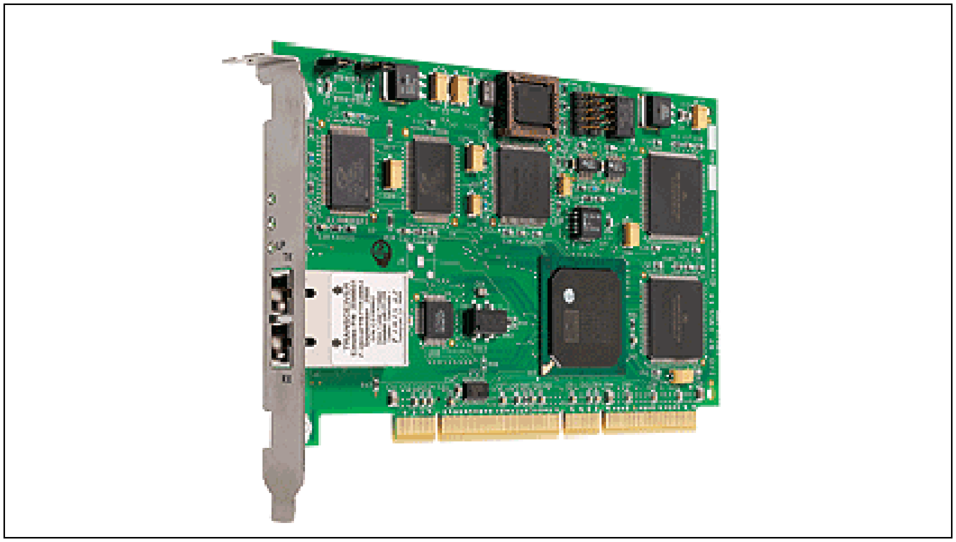


Figure 5-1 Emulex LP8000 HBA

The LP8000 also features sophisticated hardware that provides superior performance in storage area networks, delivering low latency and high throughput in switched, arbitrated loop, and clustered environments. Support for both copper and fiber optic cabling is provided through standard GBIC or embedded interfaces.

5.2.3 LP8000S

The LP8000S is a 64-bit SBus Fibre Channel HBA which has been optimized for Sun Microsystems SBus servers. It features the same 266 MIP Dragonfly ASIC as the LP8000 and offers 128 KB buffer RAM. It also supports simultaneous full duplex, which delivers up to 200 MB/s. The LP8000S features common hardware/firmware as the LP8000. Supported distances are up to 500 m, depending on the fiber optic cabling being used.

5.2.4 LP9002DC

The LP9002DC Dual Channel PCI host bus adapter offers two independent 2 Gb/s Fibre Channel HBA interfaces in a single PCI slot. It features two Emulex Centaur ASICs, two 266MIPS onboard processors, 128 KB RAM, and a high performance 64-bit 66 MHz PCI bridge.

The LP9002DC features an automatic speed negotiation capability that allows complete compatibility with existing 1 Gb/s Fibre Channel SANs, while allowing seamless upgrades to higher speed 2 Gb/s SANs. The LP9002DC architecture is based on two of Emulex's high performance 2 Gb/s HBAs integrated into one board with a PCI bridge to provide bus compatibility with PCI 2.2 based systems.

It features an optical small form factor (LC) interface that supports shortwave optics and distances up to 500 m at 1 Gb/s and 300 m at 2 Gb/s, depending on the fiber optic cabling used.

5.2.5 LP9002L

The LP9002L 64 bit, 66 MHz Fibre Channel PCI (both low profile and standard short form factor) host adapter provides support for 2 Gb/s Fibre Channel data rates. It also features a Centaur ASIC, 266 MIPS onboard processor and offers 256 KB RAM. The LP9002L features an automatic speed negotiation capability that allows complete compatibility with existing 1 Gb/s Fibre Channel SANs, while allowing seamless upgrades to higher speed 2 Gb/s SANs.

It features an optical small form factor (LC) interface that supports either shortwave or longwave optics and distances up to 10 km at both 1 Gb/s and 2 Gb/s, depending on the type of fibre optic cabling used.

5.2.6 LP9002S

The LP9002S is a 64-bit SBus Fibre Channel HBA which has been optimized for Sun Microsystems SBus servers. It features a Centaur ASIC, 266 MIPS onboard processor and offers 128 KB RAM. The LP9002S features an automatic speed negotiation capability that allows complete compatibility with existing 1 Gb/s Fibre Channel SANs, while allowing seamless upgrades to higher speed 2 Gb/s SANs.

It features an optical small form factor (LC) interface which supports shortwave optics and distances up to 500 m at 1 Gb/s and 300 m at 2 Gb/s depending on the type of fiber optic cabling.

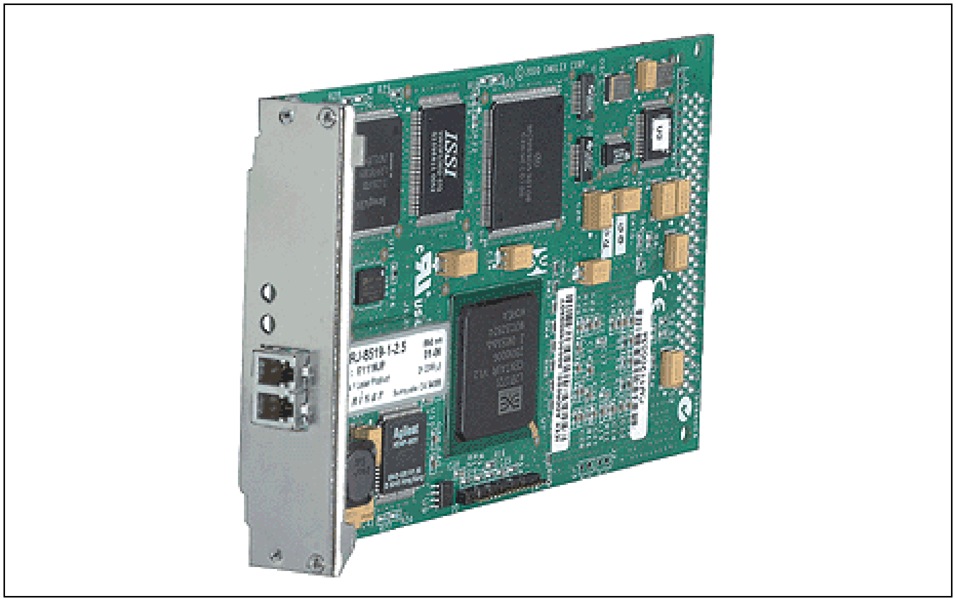


Figure 5-2 Emulex 9002S HBA (SBUS)

For a detailed comparison of all Emulex HBAs, visit Web site:

`http://www.emulex.com/products/white/fc/03-001.pdf`

5.2.7 Emulex special features

In addition to the 64-bit interface, other features unique to the Emulex HBAs are included here.

Persistent binding

This function, available with the Port driver and all UNIX drivers, allows a subset of discovered targets to be bound between a server and device. Binding can be by WWNN or WWPN. Once a configuration has been set, it will survive reboots and hardware configuration changes, as the information will be held in the registry of the server.

For example, this function may be useful for legacy tape software that expects to see its tape devices at the same SCSI Target ID at all times. By binding the tape device's WWN to a SCSI Target ID, we are able to satisfy this criteria.

LUN mapping

This function allows LUNs that are beyond NT's LUN range to be bound permanently to an NT LUN number.

5.2.8 Device drivers

A device driver is a software program that enables a server to communicate with hard drives, CD-ROM drives, printers, and other peripherals. Device drivers are stored on a hard disk and are loaded into memory at boot up.

Emulex provides two device driver options:

- Fibre Channel port driver
- Miniport driver

Each of these has a number of utilities.

The device drivers work through a common interface for all Emulex HBAs from the LP7000E through to LP9002S, allowing for a common look and feel across hardware platforms. As the device driver is used to communicate with the server, only one driver version can be loaded onto the server.

> **Note:** IBM supports the Fibre Channel port driver only. Support for the miniport driver can be requested by submitting an RPQ. For this reason we have not included details on the miniport driver.

Fibre Channel port driver

The port driver supports both persistent binding and configurable LUN mapping, and it can map up to 256 LUNs. The driver can also support both FCP and IP on a separate board. The port driver is the only version that allows a floating WWN.

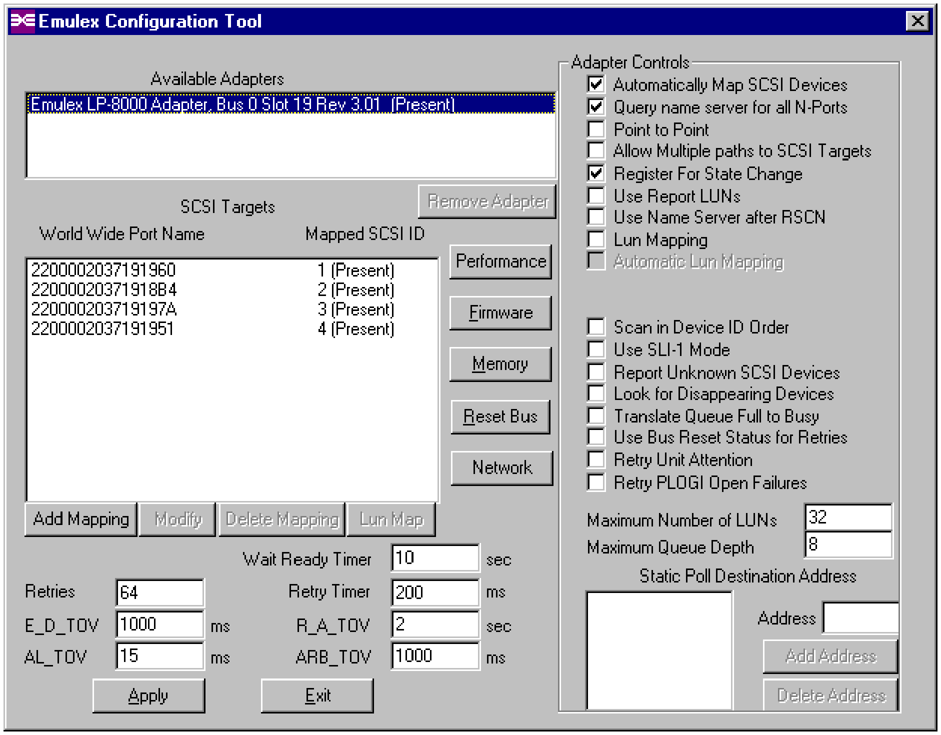
5.2.9 Emulex utilities

Depending on which device driver is selected, there are a number of utilities which enable the setup and modification of the HBA's settings. If the device driver fails to load during boot-up, the utilities will not start. This may occur if a server tried to boot and could not see any attached devices, causing internal conflicts which would prevent the driver from loading.

In this section we detail the function of the port driver utilities.

Elxcfg

Figure 5-3 shows the Emulex Fibre Channel Port Tool (elxcfg.exe) and which is installed automatically as an executable file during the Fibre Channel Port driver installation. When launched, the configuration tool will probe the registry. Adapters defined in the registry are listed in the Available Adapters list box. This list displays the adapter type, bus number, slot location, and firmware revision.



Available Adapters

Emulex LP-8000 Adapter, Bus 0 Slot 19 Rev 3.01 (Present)

SCSI Targets

World Wide Port Name	Mapped SCSI ID
2200002037191960	1 (Present)
22000020371918B4	2 (Present)
220000203719197A	3 (Present)
2200002037191951	4 (Present)

Adapter Controls

☑ Automatically Map SCSI Devices
☑ Query name server for all N-Ports
☐ Point to Point
☐ Allow Multiple paths to SCSI Targets
☑ Register For State Change
☐ Use Report LUNs
☐ Use Name Server after RSCN
☐ Lun Mapping
☐ Automatic Lun Mapping

☐ Scan in Device ID Order
☐ Use SLI-1 Mode
☐ Report Unknown SCSI Devices
☐ Look for Disappearing Devices
☐ Translate Queue Full to Busy
☐ Use Bus Reset Status for Retries
☐ Retry Unit Attention
☐ Retry PLOGI Open Failures

Maximum Number of LUNs 32
Maximum Queue Depth 8
Static Poll Destination Address
Address

Wait Ready Timer 10 sec
Retries 64
Retry Timer 200 ms
E_D_TOV 1000 ms
R_A_TOV 2 sec
AL_TOV 15 ms
ARB_TOV 1000 ms

Figure 5-3 Emulex — port driver screen

lp6dutil

lp6dutil will only run in DOS and will not run in a Windows command prompt window. It contains a full suite of diagnostics as well as utility-type functions. It is mainly used for full diagnostics.

This utility is included with the latest firmware download and is common to both driver options.

lputil

lputil is a utility used for UNIX and Novell systems to update host bus adapter firmware and Open Boot code, and lputil is included in driver downloads for each specific UNIX and Novell operating system.

5.2.10 Installation

Every Emulex host adapter is shipped with a unique World Wide Name (WWN), a serial number, and the factory installed firmware level. These numbers are clearly marked on the box and board. We recommend that you record these numbers before installation. Here is a high level overview of the installation process:

- Power off the server.
- Insert the HBA into the server.
- Connect the fabric.
- Power on the server and run the LED self-test.

5.2.11 Management

Next we discuss two methods of management.

HBAnyware

HBAnyware provides an extensible operating system-independent framework for communication with, and management of, Emulex HBAs. The framework consists of host system resident clients, agents, and services, as well as an Emulex defined command set utilizing the industry-standard Fibre Channel General Service Common Transport (FC-GS-3 CT) protocol as an in-band transport mechanism. Both host-based applications and Fibre Channel attached appliances and switches can utilize the framework. All HBAnyware operations are restricted by an access control list and are cryptographically verified using FC-GS-3 Authenticated CT.

Utilizing HBAnyware, Emulex utilities and third party applications are able to uniformly discover, report on, and manage both local and remote Emulex HBAs from a single management console or application. An integrated set of OS independent APIs, based on OS specific libraries, are included with the framework for use by host-based applications utilizing Emulex driver capabilities. Embedded environments directly attached to the fabric have equivalent capabilities via Emulex's FC-GS-3 CT based command set. In addition, a remote equivalent of the widely used Common HBA API has been added to HBAnyware. With this addition, host-based software management applications will no longer be required to deploy application specific agents to all hosts on the fabric.

MultiPulse

MultiPulse is a driver-based high availability solution that provides failover and dynamic load balancing capabilities when used with Emulex Fibre Channel or iSCSI host bus adapters. MultiPulse supports current multipathing solutions by enabling OEMs to incorporate MultiPulse technology into their own products via Emulex's APIs.

MultiPulse can monitor up to four end-to-end data paths to each configured LUN. Traffic is instantly rerouted around a failed element to protect application availability using all levels of redundancy implemented in the storage network. When a failed path is again made available, the administrator has the option of manually or automatically reinserting the path, which makes it immediately available and restores bandwidth and application availability.

In cluster configurations (such as Microsoft Cluster Server and UNIX-based clusters), MultiPulse prevents resource-induced node failovers, thereby enhancing node and application uptime. In situations where quality of service is imperative, MultiPulse can be configured with hot standby adapters and paths, guaranteeing consistent bandwidth and preventing any service degradation.

5.2.12 Troubleshooting

There are several areas that could be checked to identify a potential problem with the HBA. In the following section we look at some of the areas that should be checked during fault identification and isolation.

Common physical layer problems

Some of the symptoms of other common problems are detailed below:

- **Bad cable:** There will be a high number of I/O time-outs, the performance may be slow, or the link may be unstable, resulting in a high number of LIPs.
- **Loose GBIC:** Symptoms are similar to a bad cable and may happen when the cable is disconnected and reconnected many times.
- **Driver set for incorrect topology:** For example, the driver is configured for point-to-point, but the cable is connected to an FL_Port or other FC_AL only device.

If you are unable to resolve a problem and need to refer it to the IBM call center, you should first prepare the following information related to the HBAs:

- Versions of all Emulex software and firmware
- LED activity
- Event logs

Server operating system logs

Error messages are recorded in the standard operating systems log; for Windows this is the event log. For Solaris it is the var/adm/messages log. You can reference the event log and search for any Emulex driver related messages.

The port driver logs events under:

```
elxsli2 event id 1 through 39
```

LED status table

The LED status table, shown in Table 5-1, displays various colors and sequences that can be used to determine if the HBA is functioning correctly.

A properly functioning adapter always has at least one LED flashing. If at least one LED is not flashing, the board is likely hung or dead.

Table 5-1 LED HBA status

Green LED	Yellow LED	State
ON	Slow blink	Link up
	OFF	Link down or adapter not yet configured
OFF	Flickering	Power up or adapter reset
OFF	Fast blink	POST failure
Slow blink	Fast blink	Download in progress or no functional firmware found

A slow blink is 1 per second and a fast blink is 4 blinks per second.

FC port driver

Device driver problems can often be related to an older version of firmware. Always check that you are running the latest level of supported device drivers and firmware.

Refer to the Emulex Web site for the latest version:

http://www.emulex.com/ts/dds.html

There are optional driver registry settings that enable extra log information to be collected.

For the FC port driver, the Driver Trace Mask setting could fill the system log, but offers much more flexibility as to what is logged.

There are a number of items that can be individually logged. These values produce a bit map of the item to be logged. For example, if you wanted to trace all of these values:

- SCSI errors — 0x2
- Initialization errors — 0x40
- IOCTL command traffic — 0x80
- SCSI reset — 0x100
- Device login trace — 0x200
- Device response to PRLI — 0x8000

You would add up these values and place the result in the Driver Trace Mask value:

Driver Trace Mask = 0x83b2

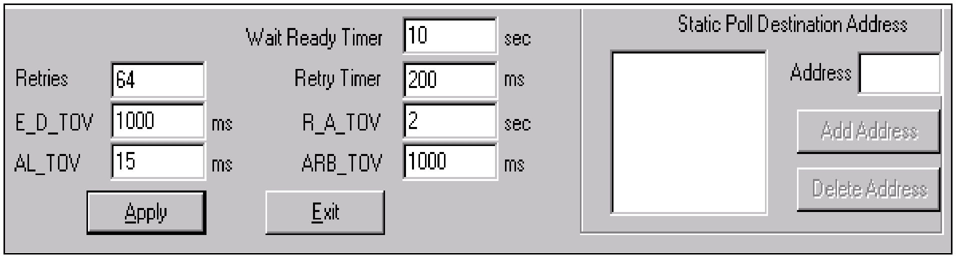
Note: Some of these values (0x1, 0x8) can potentially trace every command to and from the driver, which can potentially fill the log.

5.2.13 Performance

Some of the settings that affect performance are detailed in the following topics.

Driver settings

There are a number of adapter timer settings that can be modified. IBM recommends leaving all settings to the defaults provided by Emulex. In Figure 5-4 we show the adapter panel settings.



Wait Ready Timer 10 sec
Retries 64
Retry Timer 200 ms
E_D_TOV 1000 ms
R_A_TOV 2 sec
AL_TOV 15 ms
ARB_TOV 1000 ms
Static Poll Destination Address
Address

Figure 5-4 Emulex adapter settings

An exception to default settings would be when a server is connected to multiple storage devices. Some hardware vendors have a requirement to alter the default value settings, and they must be consulted.

For example, the recommended R_A_TOV value for one vendor is double that of the Emulex default.

R_A_TOV and E_D_TOV

These two parameters change the Resource Allocation Time-out Value and Error Detect Time-out Value respectively. If a switch is present, these values will be obtained from the switch, thus overriding any values entered in the configuration tool or registry.

HBA settings

HBA settings vary from model to model and might be set differently, depending on the platform and operating system. In Table 5-2 and Table 5-3 we show some samples of HBA settings that can be set. For current settings and specific recommendations, refer to the IBM SSG HBA and SAN Interoperability Matrix at the Web site:

http://ssddom02.storage.ibm.com/hba/hba_support.pdf

Table 5-2 LP8000 adapter recommended configuration file parameters

Parameters	Recommended settings
automap	2: Default. Automatically assigns SCSI IDs to Fibre Channel protocol (FCP) targets.
fcp-on	1: Default. Turn on FCP.
lun-queue-depth	16: Recommended when there are less then 17 LUNs per adapter. Set value = 256 ÷ (total LUNs per adapter) when there are more than 16 LUNs per adapter. If your configuration includes more than one LP8000 adapter per server, calculate the LUN-queue-depth value using the adapter with the most LUNs attached.
no-device-delay	1: Recommended. Delay to failback and I/O.
network-on	0: Default. Recommended for fabric. Do not turn on IP networking. 1: Turn on IP networking.
scan-down	2: Recommended. Use an inverted ALPA map and create a target assignment in a private loop.
topology	2: Recommended for fabric. Point-to-point topology only.4: Recommended for nonfabric. Arbitrated-loop topology only.
zone-rscn	0: Default 1: Recommended for fabric. Check name server for RSCNs.

Table 5-3 LP9000 adapter recommended configuration file parameters

Parameters	Recommended settings
automap	1: Default. SCSI IDs for all FCP nodes without persistent bindings will be automatically generated. If new FCP devices are added to the network when the system is down, # there is no guarantee that these SCSI IDs will remain the same # when the system is booted again. If one of the above fcp binding methods is specified, then automap devices will use the same mapping method to preserve CSI IDs between link down and link up. If no bindings are specified above, a value of 1 will force WWNN binding, 2 for WWPN binding, and 3 for DID binding. If automap is 0, only devices with persistent bindings will be recognized by the system.
fcp-on	1: Default. Turn on FCP.
lun-queue-depth	30: The default value lpfs will use to limit the number of outstanding commands per FCP LUN. This value is global, affecting each LUN recognized by the driver, but may be overridden on a per-LUN basis. RAID may want to be configured using the per-LUN tunable throttles.
no-device-delay	0: Default. Implies no delay whatsoever. 1: Recommended. 2: Setting a long delay value may permit I/O to build up, each with a pending timeout, which could result in the exhaustion of critical Solaris kernel resources. In this case, you may see a fatal message such as PANIC: Timeout table overflow
network-on	0: Default. Recommended for fabric. Do not turn on IP networking. 1: Turn on IP networking.
scan-down	0: Recommended. Causes the lpfs driver to use an inverted ALPA map, effectively scanning ALPAs from high to low as specified in the FC-AL annex. 2:Arbitrated loop topology.
tgt-queue-depth	0: Recommended. The default value lpfs will use to limit the number of outstanding commands per FCP target. This value is global, affecting each target recognized by the driver, but may be overridden on a per-target basis (see below). RAID may want to be configured using the per-target tunable throttles.
topology	2: Recommended for fabric. Point-to-point topology only. 4: Recommended for nonfabric. Arbitrated-loop topology only.
xmt-que-size	256: Default. Size of the transmit queue for mbufs (128 - 10240).
zone-rscn	0: Default 1: Recommended for fabric. Check name server for RSCNs. Setting zone-rscn to 1 causes the driver to check with the NameServer to see if an N_Port ID received from an RSCN applies. If soft zoning is used with Brocade fabrics, this should be set to 1.

External boot function

Emulex HBAs provide the ability to perform an external server boot from a Fibre Channel device. The boot BIOS is disabled by default and must be enabled with the lp6dutil or GUI utility. You can define up to eight boot devices configured by Device ID or WWPN. The boot BIOS supports up to eight FC HBAs per server.

Firmware structure

Emulex provides two versions of zipped firmware; an AWC and DWC. The AWC file will update all layers of the firmware structure except for the Config layer. The DWC updates the same layers as the AWC with the exception of the Adapter Boot - POST layer. The Adapter BOOT- POST contains a kernel and is essential for normal operation.

As an AWC firmware load will update the Adapter BOOT - POST region, if the firmware load is interrupted during an update to the kernel, it could destroy the HBA. For this reason it is not recommended to download an AWC firmware load directly to the HBA. With the DWC firmware load, if the update process is interrupted, the POST code is not affected and the download process can be retried. The firmware readme file contains information on the regions and should be referred to prior to the load.

Typically, major firmware changes, for example from 1.0 to 2.0, will require an AWC load. For interim changes, for example from 2.0 to 2.1, refer to the readme file to determine if an AWC or DWC load is required.

Note: For all other firmware loads, it is recommended to perform a DWC load.

In Table 5-4 we describe each layer of the firmware.

Table 5-4 Emulex firmware structure

Layer	Description
Adapter Boot - POST	Contains kernel — essential for normal operation
ENDEC Loop Back	POST code for the internal ENDEC loop back
Stub	Loads either SLI-1 or SLI-2 function firmware
Boot BIOS (optional)	Optional INT13 boot BIOS
SLI - 1 Overlay	SLI-1 functional firmware
SLI - 2 Overlay	SLI-2 functional firmware
Config Regions	Non-volatile configuration parameters

5.3 JNI

IBM currently also markets a broad range of Fibre Channel HBAs from JNI. These HBAs operate in a number of operating systems environments, including Solaris, Microsoft Windows in multiple server and cluster environments, Hewlett Packard HP-UX, IBM AIX, Red Hat Linux, Novell NetWare, and Apple Mac OS. In the following sections we have listed the IBM supported offerings.

5.3.1 FCI-1063-N 32-bit PCI to FC HBA

The JNI FCI-1063 is a 32-bit PCI-to-FC Adapter with an Integrated Optical Short-Wave Dual SC Connector Interface. The FCI-1063-N provides a full-duplex 1.0623 Gb Fibre Channel connection between PCI Sun servers and SAN devices.

5.3.2 FC64-1063-N 64-bit SBus to FC HBA

The JNI FC64-1063-N 64-bit SBus-to-FC Adapter with an Integrated Optical Short-wave Dual SC Connector Interface. The FC64-1063-N provides a full-duplex 1.0623 Gb Fibre Channel connection between SBus Sun servers and SAN devices. In Figure 5-5 we show a picture of the FC64-1063-N HBA.

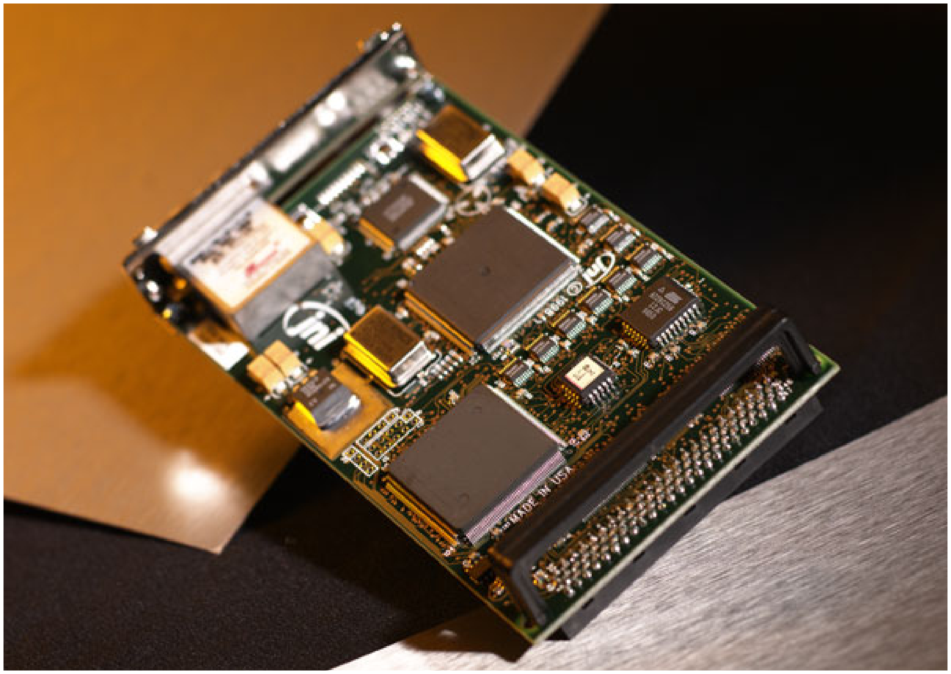


Figure 5-5 Picture of JNI's FC64_1063 HBA

5.3.3 FCE-1063 64-bit SBus to FC HBA

The JNI FCE-1063 is a 64-bit SBus-to-FC Adapter with an Integrated Optical Short wave SC Connector Interface. The FCE-1063 is backward-compatible with 32-bit SBus Sun servers and provides a full-duplex 1.0623 Gb Fibre Channel connection between SBus Sun servers and SAN devices.

5.3.4 FCE2-1063 64-bit Dual Port SBus to FC HBA

The JNI FCE2-1063 is a 64-bit Dual Port SBus-to-FC Adapter with Integrated Optical Short wave Dual SC Connector Interfaces. The FCE-1063 supports 32-bit or 64-bit data transfer paths and provides a full-duplex 1.0623 Gb Fibre Channel connection between SBus Sun servers and SAN devices.

5.3.5 FCE-1473 1 or 2 Gb 64-bit SBus to FC HBA

The JNI FCE-1473 is a 64-bit Single Port SBus-to-FC Adapter with an Integrated Short wave LC small factor Optical Interface. The FCE-1473 supports 32-bit and 25 MHz and 64-bit data paths. The FCE-1473 is a full featured 1 Gb/s or 2 Gb/s full duplex HBA that supports automatic rate negotiation seamlessly on demand. The FCE-1473 also features both local and fabric boot capabilities.

5.3.6 FCE-6410 64-bit PCI to FC HBA

The JNI FCE-6410 is a 64-bit PCI-to-FC Adapter with an Integrated Optical Short-wave SC Connector Interface. The FCE-6410 supports 32-bit and 64-bit data paths at 33 MHz and provides a full-duplex 1.0623 Gb/s Fibre Channel connection between multiple OS (IBM AIX, Red Hat Linux, Novell Netware, Sun Solaris, HP-UX, Windows, Mac OS) servers, and SAN devices. The FCE-6410 provides multiple OS support through two JNI products (UNIX DriverSuite, PC DriverSuite), bundled with the HBA.

5.3.7 FCE2-6412 64-bit Dual Port PCI to FC HBA

The JNI FCE2-6412 is a 64-bit Dual Port PCI-to-FC Adapter with Integrated Optical Short-wave Dual SC Connector Interfaces. The FCE-6412 supports 64-bit data paths at 33 MHz and 66 MHz and provides a full-duplex 1.0623 Gb/s Fibre Channel connection between multiple OS (IBM AIX, Red Hat Linux, Novell Netware, Sun Solaris, HP-UX, Windows, Mac OS) servers, and SAN devices. The FCE2-6412 provides multiple OS support through two JNI products (UNIX DriverSuite, PC DriverSuite), bundled with the HBA.

5.3.8 FCC-6460 1 or 2 Gb Compact PCI to FC HBA

The JNI FCC-6460 is a 64-bit Dual Port PCI-to-FC Adapter with an Integrated Optical Short-wave LC small form factor Connector Interface. The FCC-6460 supports 64-bit data paths and is a full featured 1 Gb/s or 2 Gb/s full duplex HBA between Sun Servers and SAN devices and supports automatic rate negotiation seamlessly on demand. The FCC-6460 is also hot swappable.

5.3.9 FCE-6460 1 or 2 Gb 64-bit PCI to FC HBA

The JNI FCE-6460 is a 64-bit Single Port PCI-to-FC Adapter with an Integrated Optical Short-wave LC small form factor Connector Interface. The FCE-6460 supports 64-bit data paths at 33 MHz or 66 MHz and is a full featured 1 Gb/s or 2 Gb/s full duplex HBA that supports automatic rate negotiation seamlessly on demand. The FCE-6460 also contains SNIA library support for management applications in Solaris or Windows.

Note: All JNI Fibre Channel HBAs support fabric boot capabilities.

5.3.10 Drivers

Both the FCI_1063 and FC64_1063 run the Solaris driver. This driver supports 2.6, 7, and 8 versions of SUN Solaris. **`fca-pci.pkg`** is the SCSI driver package used in Solaris with the JNI 32-Bit PCI adapter and **`fcaw.pkg`** is used with the 64-bit SBus adapter.

To view the adapter's properties, type in a **`show-devs`** command to determine the location of your adapter (remember you are looking for 1242, 4643 or Fibre Channel). Now **`cd`** to the directory where the JNI adapter card is located. Once you **`cd`** to the directory, type in the command **`properties`**. Make sure you set the Open Boot parameter auto-boot to false. Remember that you must be connected to a device or have a loopback plugged into the adapter before you can view the adapter properties.

Prior to installing the driver, you can enter the following command to perform a basic test to determine if the Open Boot can recognize the JNI adapter card:

```
Show-devs
```

LUN level masking

With the JNI EZ Fibre software you have the ability to implement LUN-Level Zoning at the host bus adapter level. The LUN-Level Zoning option comes standard on all JNI adapter cards and offers the following advantages:

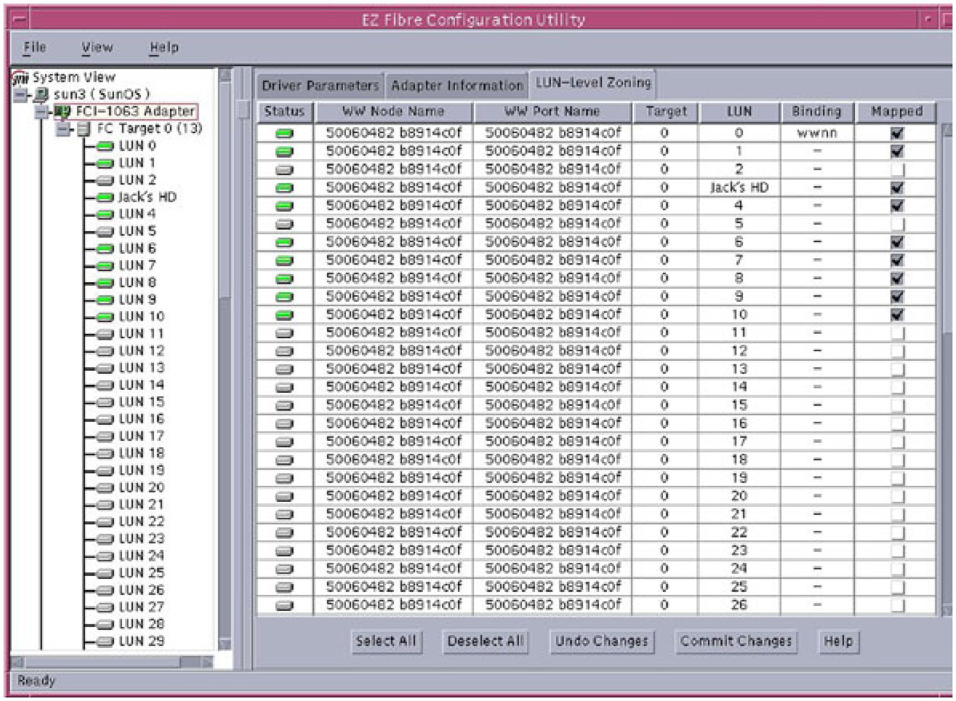
- Shorter boot-up time by controlling device discovery process in multiple CPU environments
- Flexibility (dynamic allocation, the ability to change drives “on the fly”)
- Allocation of backup resources (one can allocate backup within a tape array itself)
- Zero % performance loss (since the zoning has been pre-configured, the operating system does not incur the overhead of determining resource availability)
- Enhanced security using JNI’s host-based LUN-Level Zoning.

5.3.11 Management

JNI’s proprietary software, EZ Fibre, is used for configuring and managing a Fibre Channel installation. EZ Fibre is a Windows-based program that comes with on-screen help, a troubleshooting guide, and customer support options. In Figure 5-6 we show the EZ Fibre configuration utility, which is the fastest and easiest way to install and configure JNI host bus adapters.

EZ Fibre allows you to link your servers to RAIDs, JBODs, and other storage devices through a high-speed Fibre Channel network. You can map the SAN fabric all the way down to the LUN level, while viewing a graphical interface of the Fibre Channel devices attached to JNI adapters.

EZ Fibre dynamically discovers new targets attached to the FC link, and through its GUI allows the administrator to easily set and manage the host bus adapter parameters. Such “hot-pluggable” capabilities minimize the steps necessary to grow a SAN or swap out a bad disk drive.



Status	WW Node Name	WW Port Name	Target	LUN	Binding	Mapped
🟩	50060482 b8914c0f	50060482 b8914c0f	0	0	wwnn	☑
🟩	50060482 b8914c0f	50060482 b8914c0f	0	1	–	☑
⬜	50060482 b8914c0f	50060482 b8914c0f	0	2	–	□
🟩	50060482 b8914c0f	50060482 b8914c0f	0	Jack's HD	–	☑
🟩	50060482 b8914c0f	50060482 b8914c0f	0	4	–	☑
⬜	50060482 b8914c0f	50060482 b8914c0f	0	5	–	□
🟩	50060482 b8914c0f	50060482 b8914c0f	0	6	–	☑
🟩	50060482 b8914c0f	50060482 b8914c0f	0	7	–	☑
🟩	50060482 b8914c0f	50060482 b8914c0f	0	8	–	☑
🟩	50060482 b8914c0f	50060482 b8914c0f	0	9	–	☑
🟩	50060482 b8914c0f	50060482 b8914c0f	0	10	–	☑
⬜	50060482 b8914c0f	50060482 b8914c0f	0	11	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	12	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	13	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	14	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	15	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	16	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	17	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	18	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	19	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	20	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	21	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	22	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	23	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	24	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	25	–	□
⬜	50060482 b8914c0f	50060482 b8914c0f	0	26	–	□

Figure 5-6 EZ Fibre configuration panel

5.3.12 Installation

Every JNI host bus adapter is shipped with a unique World Wide Name (WWN). These numbers are currently located via the EZ Fibre software shipped with the cards.

We recommend that you record these numbers before installation.

Before installing the adapter card, ensure that the adapter is of the correct type. The adapter will only operate when connected to devices of the same type. In Figure 5-7 we show the FCI-1063-N.

The standard SBUS back plate includes a two-tab extender bar. Check your system to see if the adapter bar is required. If the bar needs to be removed, use the screwdriver supplied to remove the two small Phillips head screws, which mount the bar to the back plate.

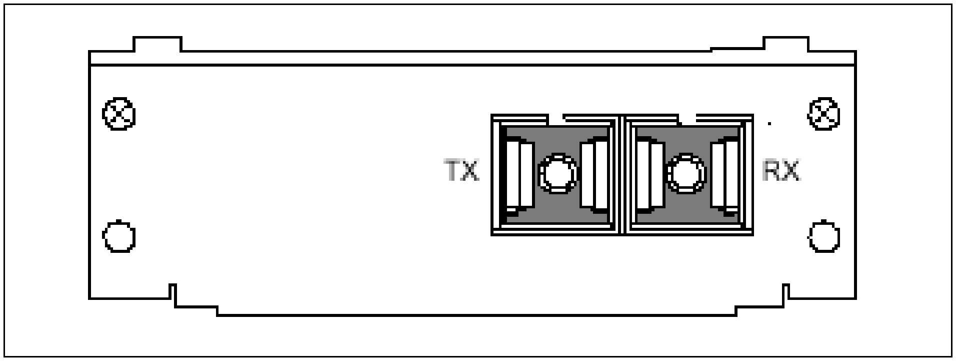


Figure 5-7 The FCI-1063_N 64 Optical device

Next we describe is a high-level overview of the installation process. There are slight differences, depending on which model of SUN server you are configuring:

- Power off the server
- Insert the HBA into the server
- Connect fabric
- Power on the server

5.3.13 Troubleshooting the SBUS HBA

In this section, we show some troubleshooting hints and tips for the SBUS HBA.

Is dynamic reconfiguration supported?

The fcaw driver supports Dynamic Reconfiguration.

I cannot see the adapter with show-sbus or show-devs.

Verify that the adapter is properly seated, then turn the power on. Check the probe-list by typing in the command **`printenv`** and look for the Open Boot parameters **`sbus-probe-list`** or `sbus-probe-default`.

Two columns should appear. The first column displays the slots on the computer that are being probed. The second column displays all possible slots to be probed. Compare the two columns and find the slot that is not being probed. Enter slot into the probe list. To reset the probe list to include the slots, use the command:

```
setenv sbus-probe-list or sbus-probe-default = (NNNN)
```

“NNNN” represents all slots to be probed.

5.3.14 Troubleshooting the JNI PCI HBA

In this section, we give some troubleshooting hints and tips for the PCI HBA.

I cannot see the adapter with show-sbus or show-devs command.

Verify that the adapter is properly seated, then turn power on. Check the probe-list by typing in the command **printenv** and look for the Open Boot parameters **pci-probe-list**.

Two columns should appear. The first column displays the slots on the computer that are being probed. The second column displays all possible slots to be probed. Compare the two columns and locate the slot that is not being probed Enter the slot into the probe list. To reset the probe list to include the slot, use the command:

```
setenv pci-probe-list = (NNNN)
```

“NNNN” represents all slots to be probed. Make sure the PCI adapter is in the correct slot. It must be 33MHz, 5 volt and 2.1 PCI compliant.

I get an error that the driver fails to initialize.

Check **fca-pci.conf** for **fca_nport**. In Solaris view the **fca-pci.conf**. The file is found in the `/kernel/drv directory-ry`. Type in `more fca-pci.conf`. Verify that the parameter **fca_nport** is correctly set. Remember that the configuration flag **fca_nport** is a Boolean Type value. The default is 0 (false). If false (0), fca initializes on a loop. If true (1), fca initializes as an N_Port and fabric operation is enabled. The parameter looks like this:

```
fca_nport = 0;
```

Also check that the drives are attached correctly, or if the cables are faulty. You may also receive continuous Elastic Store errors from the driver.

5.3.15 Troubleshooting both PCI and SBUS

In this section we look at some common problems and detail some specific settings IBM recommends when connecting to the ESS.

The drives were not added.

Perform the **drvconfig** and **disks** command.

Check the file `/kernel/drv/sd.conf`. This file determines the targets and LUNs the target drive will probe for. If the targets/LUNs you are attaching do not appear, edit the file and add them. Halt the system and perform a **boot-r**.

I do not see all my targets and LUNs.

You must have all targets and LUNs in the **sd.conf** file for Solaris to recognize them. The **sd.conf** file is found in the **/kernel/drv**. By default you will have targets 0-6 and 7-15 with one LUN under each target.

Here is an example of how each line should look:

```
   name=l.sdlT class=lsscsil@ target=N lun=0; (where N is the target number)
```

Enter this number into **sd.conf** with the appropriate number of LUNs. There should be one LUN under each target. A reconfiguration boot is required after editing the **sd.conf** file before the device is recognized by Solaris. Type in the Solaris command **drv- config**. This command goes out and looks for new devices attached to the JNI adapter cards (remember that the targets and LUNs must be configured in the **sd.conf** before trying this command). After the **drv-config** command, you will receive a new prompt. At this prompt, type in the command **disks** and press Enter. Verify the presence of the new targets by entering the **format** command.

Disk problems can also affect device recognition.

I cannot see my targets over a switch.

Make sure the cables are correctly plugged in and there is a link (on the switch). Make sure that in the configuration file (**fcaw.conf**), the parameter **fca_nport** is set to 1.

As an example:

```
Configuration flag fca_nport
Type: Boolean; default: 0 (false)
If false (0), then fca initializes on a loop
If true (1), then fca initializes as an N_Port and fabric operation is enabled
fca_nport = 1;
```

After I reboot, I receive Target_Queue full error.

The **sd_max_throttle** variable is the maximum number of commands that the SCSI sd driver will attempt to queue to the HBA driver (fcaw). The default value is 256. If **sd_max_throttle** is set at its default you will receive the error:

```
PCI - fca-pci0: fca_highintr: Target Queue Full. Packet Rejected!
SBUS - fca0: fca_highintr: Target Queue Full. Packet Rejected!
```

Refer to “sd_max_throttle” on page 172 for the IBM recommended setting, and download the JNI driver 2.4 or later. This driver fixes the queue-full condition.

5.3.16 Performance settings

In this section we look at the recommended IBM values for the FCI-1063 and FC64-1063 when connecting to an ESS. These values can be located in the manual *IBM TotalStorage ESS 2105,* SC26-7446.

System settings

All values can be located in the Systems file, which can be found in the **`/etc`** directory.

The two parameters that need to be edited are the *sd_max_throttle* and the *maxphys*.

sd_max_throttle

This parameter specifies the maximum number of commands that the sd driver will queue to the host bus adapter driver. The recommended value is 16 for Fibre Channel configurations with less than 17 LUNs per adapter. The default value value is 256, but you must set the parameter to a value less than or equal to the maximum queue depth for each LUN connected. For configurations with greater than 16 LUNs per adapter, use the following formula for each adapter:

```
sd_max_throttle=256 / (LUNs per adapter)
```

Where LUNS per adapter is the largest number of LUNS assigned to a single adapter.

Use the adapter with the highest number LUNs attached when calculating the lun-queue-depth value for servers with more than one adapter installed.

```
set sd:sd_max_throttle=5
```

If you are using version 2.4 of the driver or later, **`sd_max_throttle`** need not be reduced. The target driver (fcaw) will respond by single-threading all subsequent I/O, which has a negative impact on performance (when Solaris overloads the target with commands, the target will reject subsequent SCSI commands because its internal queues will register as full. The Solaris response will be to only send one command at a time — which in turn will lower performance).

sd_io_time

This parameter specifies the time-out value for disk operations. Add the following lines to the **`/etc/system`** file to set the sd_io_time parameter for the ESS LUNs:

```
set sd:sd:_io_time=0x78
```

sd_retry_count

This parameter specifies the retry count for disk operations. Add the following lines to the **`/etc/system`** file to set the **`sd_retry_count`** parameter for the ESS LUNs:

```
set sd:sd_retry_count=5
```

maxphys

This parameter specifies the maximum number of bytes you can transfer for each SCSI transaction. The default value is 126976 (124 KB). If the I/O block size requested exceeds the default value, the request is broken into more than one request. The value should be tuned to the intended use and application requirements. For maximum bandwidth, set the maxphys parameter by adding the following line to the `/etc/system file`:

```
set maxphys=8388608
```

If you are using Veritas volume manager on the ESS LUNs, you must set the VxVM max I/O size parameter, (**`vol_maxio`**) to match the **`maxphys`** parameter. For example, if you set the **`maxphys`** parameter to 8388608 you will need to add the following line to the **`/etc/system`** file to set the **`VxVM I/O`** size also to 8 MB:

```
set vxio:vol_maxio=16384
```

HBA settings

HBA settings vary from model to model and might be set differently depending on the platform and operating systems. These are samples of HBA settings that can be set. For current settings and specific recommendations refer to the IBM SSG HBA and SAN Interoperability Matrix at the Web site:

http://ssddom02.storage.ibm.com/hba/hba_support.pdf

Table 5-5 IBM recommended settings for JNI FC64-1063 and JNI FCI-1063

Parameters	Recommended settings
FcLoopEnabled FcFabricEnabled	For direct attachment, set FcLoopEnabled=1 and FcFabricEnabled=0, For fabric attachment, set FcLoopEnabled=0 and FcFabricEnabled=1
fca_nport	0 = default, initializes on a loop. 1 = recommended for fabric, initializes as an N-Port
public loop	0 = default, recommended, initialize according to what fca_nport is set for disabled
ip_disable	0 = default, IP side of the driver is enabled. 1 = recommended for fabric, IP side of the adapters is completely disabled.

Parameters	Recommended settings
failover	60 -recommend without McDATA switch, 300 -recommended with McDATA switch.
busy_retry_delay	500 -recommended, delay between retries after device returns busy response for a command.
scsi_Probe_delay	5000 -recommended, delay before SCSI probes are allowed during boot

In Table 5-6 we show settings for other JNI adapters.

Table 5-6 JNI miscellaneous recommended settings

Parameters	Recommended settings
FcEngHeartbeatInterval	5: Default. When the JNI adapter/driver detects that the Fibre Channel link is up (and there is no I/O activity), it will send a test frame (or heartbeat) to itself to verify link integrity. The test frame is sent at the interval specified by this parameter. If the test frame does not complete, it is assumed that there is a link problem. In this situation, the driver initiates error recovery to re-establish a good link. A value of 0 disables the heartbeat
FcLinkUpRecoveryTime	1000: Default. Delay (msec) after the link is up before port discovery begins, allowing the link to stabilize and protecting against a possible I/O surge. This timer is reset every time the link comes up. The default value is adequate for most configurations.
BusyRetryDelay	5000: Default. Delay (msec) before retrying after receipt of an I/O with a SCSI Busy status from a target. The number of retries is based on the Solaris retry count associated with the I/O.
FailoverDelay	30: Delay (seconds) before failing all I/O for an offline target. If the delay timer expires, all I/O for the failed target is returned to the application. A zero value disables failover.
TimeoutResetEnable	0: False. Boolean parameter for enabling SCSI target resets for timed out I/O. When the timer expires (usually 60 seconds, as specified by the upper layers), the driver issues a target reset to attempt to clear the device (which might be either too busy to respond or stuck).

Parameters	Recommended settings
QfullRetryCount	5: Default. Number of times an I/O is retried due to receipt of a SCSI queue full status from a target. The delay between retries is based on the QfullRetryDelay parameter.
QfullRetryDelay	5000: Default. Delay (msec) before retrying after receipt of an I/O with a SCSI queue full status from a target. The number of retries is based on the QfullRetryCount parameter.
LunRecoveryInterval	50: Default. Sets the LUN I/O recovery interval (in msec) after the driver reconnects to a disk. It is a global parameter affecting all targets, and determines how long the driver waits after a port is discovered until sending I/O to that port. Some devices might require more time to flush I/O that was in progress prior to a link going down; if this is the case, increase the value of this parameter.
FcLinkSpeed	3: Default. Specifies the desired Fibre Channel link speed as follows: v 0: default to SEEPROM setting v 1: force 1 gigabit per second v 2: force 2 gigabit per second v 3: auto negotiate link speed
JniCreationDelay	5: Default. Delay (seconds) after driver creation to allow the network to stabilize, discover ports, and build the driver's database. Increase this value if targets are being discovered too late in the boot process.
FlogiRetryCount	3: Default. Total number of Fabric Login (FLOGI) attempts before giving up logging in to a switch. Failure prevents participation on a Fabric topology.
FcFlogiTimeout	10: Default. Specifies the amount of time (in seconds) that the driver waits for a Fabric Login (FLOGI) accept. The value should be increased only if the switch to which the HBA is connected requires more time to respond to a FLOGI. The number of retries is configured with the FlogiRetryCount parameter.

Parameters	Recommended settings
PlogiRetryCount	5: Default. Total number of Port Login (PLOGI) attempts before giving up logging in to a SCSI target.
PlogiControlSeconds	30: Default. Defines the number of seconds that the driver waits for a successful port login (PLOGI) attempt. The maximum number of attempts is defined by the PlogiRetryCount parameter. Some devices might take longer to respond to PLOGIs; if this is the case, increase the value of this parameter.
FcEmldEngTcbCount.	1789: Default. Total number of concurrent exchanges (also called transfer control blocks) allowed by the adapter. To optimize performance, set this parameter to match the memory capacity of the hardware

Boot BIOS

All JNI HBAs support external boot.

5.4 QLogic

IBM provides support for the QLogic family of Fibre Channel HBAs. This includes specific HBAs in the QLA2100, QLA2200 and QLA 2300 series. QLogic Fibre Channel HBA products have achieved SANMark certification, which is the industry standard for device compatibility. The HBAs are based on single chip architecture, providing high reliability and low power consumption. In addition, they are able to boot to an external FC storage device, either on a local loop or through a switched fabric.

For a complete list of supported drivers and configurations, refer to the Web site:

```
http://www.qlogic.com
```

5.4.1 QLA2100

QLogic's first generation of Fibre Channel HBA products is the QLA2100 family. These cards are currently available as either fixed copper (QLA2100/66) or optical (QLA2100F/66) nodes, IBM only supports the optical version. The /66 indicates the maximum supported PCI bus speed. These are 64-bit PCI cards that also function in 32-bit PCI environments. The HBAs use the ISP2100 ASIC.

The 2100 HBAs operate at 1Gb/s data rate on the Fibre Channel medium. These products support either FC-AL or switched fabrics using an FL_Port connection.

In Figure 5-8 we show the QLogic HBA card.

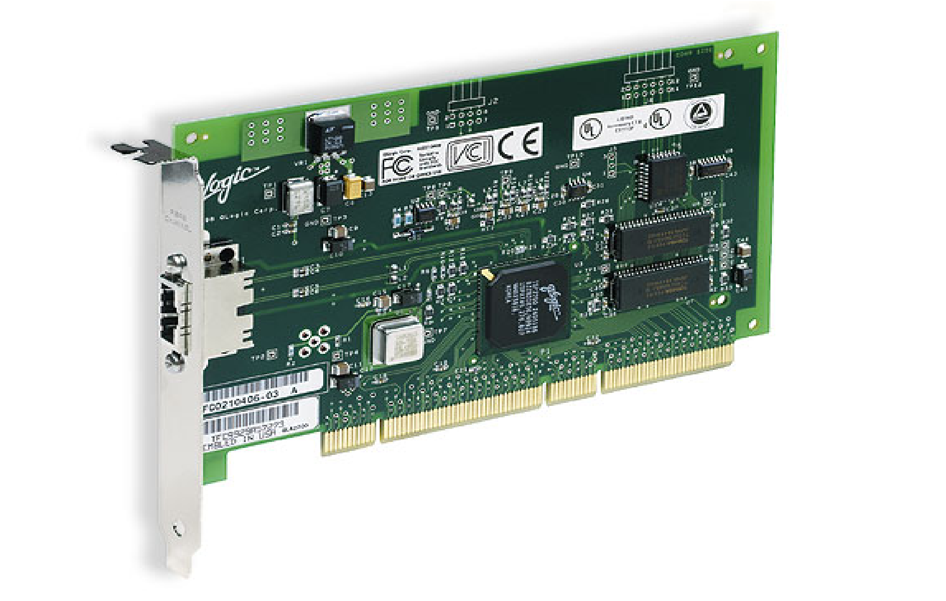


Figure 5-8 QLogic HBA card

5.4.2 QLA2200

QLogic's second generation of performance optimized Fibre Channel HBA's is the QLA2200 series. These boards are based on QLogic's ISP2200 ASIC. As with the 2100 series, these are PCI cards that operate in 33 and 66 MHz as well as 32 and 62-bit environments. The 2200 series supports FC-AL as well as switched fabric via F_Port and FL_Port connections. Additionally, the QLA2200 series is able to support IP protocol. The QLA2200 series supports Class 2, 3, and FC Tape. This family of boards is available in the following configurations: IBM supports the QLA2200F, QLA2202F for connections to the ESS.

> **Note:** QLA2202 is supported only on the NAS 300G R2.5.

For a detailed description of each QLA2200 HBA, refer to the following Web site:

```
http://www.qlogic.com/products/sanblade/sanblade_2200.asp
```

5.4.3 QLA2300

The QLogic SANblade 2300 Series Fibre Channel host bus adapters (HBAs) offer 2 Gb/s performance. They are available in PCI-X form factor, which is backwardly compatible with PCI. SANblade 2300 Series HBAs have an integrated RISC processor, the fibre protocol engine and transceivers in a single, Fibre Channel controller chip. Each HBA features 256 KB RAM per port, supports FC-AL, FCAL-2, point-to-point, switched fabric and Class 3 service. Supported HBAs include the QLA2300F, QLA2310FL and the QLA2340L

Note: QLA2300F is supported for a Brocade fabric only.

For a detailed description of each QLA2300 HBA, refer to the following Web site:

http://www.qlogic.com/products/sanblade/sanblade_2300.asp

5.4.4 Installation

Refer to the *IBM Enterprise Storage Server Host Systems Attachment Guide, 2105 Models E10, E20, F10 and F20*, SC26-7296 for specific installation instructions.

5.4.5 Management

QLogic offers management software with every HBA. IBM also offers a customized version called FasT-MSJ. The QLogic SANsurfer Tool Kit CD is included with every HBA. Contained on the CD is SANsurfer software that simplifies management by making setup, configuration and maintenance easy along with enabling features such as remote management, load balancing, failover and persistent binding. In addition, the easy to use SANblade Control FX wizard based utility is provided for installation, configuration and diagnostic functions. SANblade Control FX is delivered with your drivers. The SANblade 22xx/23xx is also fully compatible with management applications that support the SNIA API, allowing IT managers to reduce HBA management time and lower their total cost of ownership.

5.4.6 Troubleshooting

For detailed debugging, experienced users may prefer to use the Event Viewer that ships with Windows.

Events logged by the driver are listed with the Source field set to “ql2100” or “ql2200” and the Event field set to “11”. Double-clicking on the event entry will allow you to view the event details, then set the data format to “Words”. The detailed event code is displayed at hexadecimal offset x‘34’.

For some of the event codes, additional data will be recorded in the least significant 16 bits of the long word. Additional data may also be recorded in the long word at offset 10 (hex).

There is a FAST!UTIL parameter to enable “additional event logging”, the default is disabled.

Events that are logged without extended event logging being enables are “true” error events (those without a "*" or "**" in front of them). In general, these error events are logged because of some error conditions. Contact QLogic customer support if you encounter these error events.

5.4.7 Performance

All QLogic PCI cards store user configurable data in the hardware. HBA settings vary from model to model and might be set differently depending on the operating system. These are samples of HBA settings that can be set. For current settings and specific recommendations refer to the IBM SSG HBA & SAN Interoperability Matrix:

http://ssddom02.storage.ibm.com/hba/hba_support.pdf

These may include the following.

Frame Size

This setting specifies the maximum frame length, the default sized for the LA22xx board is 1024 and 2048 for the LA23xx board. If using F_Port (point-to-point) connections, change this setting to 2048 for maximum performance.

Loop Reset Delay

After resetting the loop, the firmware refrains from initiating any loop activity for the number of seconds specified in this setting. The default is 5 seconds.

Adapter Hard Loop ID

This setting forces the adapter to attempt to use the ID specified in the Hard Loop ID setting. The default is disabled.

Hard Loop ID

If the Adapter Hard Loop ID setting is enabled, the adapter attempts to use the ID specified in this setting. The default ID is 0 (disabled).

Execution Throttle

This setting specifies the maximum number of commands executing on any one port. When a port's execution throttle is reached, no new commands are executed until the current command finishes executing. The valid options for this setting are 1-256. The default (optimum) is 16.

LUNs per Target

This setting specifies the number of LUNs per target. Multiple LUN support is typically for RAID boxes that use LUNs to map drives. Options include 0,8.16,32,64,128 or 256. The default is 8. If you do not need multiple LUN support, set the number of LUNs to 0.

Enable LIP Reset

This setting determines the type of loop initialization process (LIP) reset that is used when the operating system initiates a bus reset routine. When this setting is Yes, the driver initiates a global LIP reset to clear the target device reservations. When this setting is No, the driver initiates a global LIP reset with full login. The default is No.

Enable LIP Full Login

This setting instructs the ISP chip to re-login to all ports after any LIP. The default is enabled.

Enable Target Reset

This setting enables the drivers to issue a Target Reset command to all devices on the loop when a SCSI Bus Reset command is issued. The default is disabled.

Login Retry Count

This setting specifies the number of times the software tries to log in to a device. Options are 0-255, the default is 8 retries.

Port Down Retry Count

This setting specifies the number of times the software retries a command to a port returning port down status. Options are 0-255, the default is 8 retries.

Extended Error Logging

This setting provides additional error and debug information to the operating system. When enabled, events are logged into the Windows NT Event Viewer. The default is disabled.

Operation Mode

This setting specifies the reduced interrupt operation (RIO) modes, if supported by the software driver. RIO modes allow posting multiple command completions in a single interrupt (see the QLogic hardware install manual for complete description of usage). The manuals are available on the QLogic Web site. The default is 0 disabled.

Connection Options

This setting defines the type of connection (loop or point-to-point) or connection preference: 0 = loop only, 1 = point-to-point only, 2 = loop preferred, otherwise point-to-point, 3 = point-to-point, otherwise loop. The QLogic default is 2.

Interrupt Delay Timer

This setting contains the value (in 100-microsecond increments) used by a timer to set the wait time between accessing (DMA) a set of handles and generating an interrupt. The default is 0. Only applies the QLA23xx adapter.

In Table 5-7 we show the recommendations for the QLA2200F.

Table 5-7 QLA2200F recommendations

Parameters	Recommended settings
hba0-max-frame-length	2048
hba0-max-iocb-allocation	256
hba0-execution-throttle	31
hba0-login-timeout	4
hba0-login-retry-count	1
hba0-fabric-retry-count	10
hba0-enable-adapter- hard-loop	0
hba0-adapter-hard-loop-ID	0
hba0-enable-64bit-addressing	0
hba0-enable-LIP-reset	0
hba0-enable-LIP-full-login	1
hba0-enable-target-reset	0: non-clustered, =1: clustered
hba0-reset-delay	5
hba0-port-down-retry-count	30
hba0-link-down-error	1
hba0-loop-down-timeout	60

Parameters	Recommended settings
hba0-connection-options	1: switched fabric 2: point-to-point
hba0-device-configuration-mode	1
hba0-fc-tape	0
hba0-command-completion-option	1

In Table 5-8 we show the QLA2310F, QLA2340, and QLA2342 recommended settings.

Table 5-8 QLogic QLA2310F, QLA2340, QLA2342 recommendations

Parameters	Recommended settings
hba0-max-frame-length	2048
hba0-max-iocb-allocation	256
hba0-execution-throttle	31
hba0-login-timeout	4
hba0-login-retry-count	1
hba0-fabric-retry-count	10
hba0-adapter-hard-loop-ID	0
hba0-enable-64bit-addressing	0
hba0-enable-LIP-reset	0
hba0-enable-LIP-full-login	1
hba0-enable-target-reset	0: disabled
hba0-reset-delay	5
hba0-port-down-retry-count	30
hba0-link-down-error	1
hba0-loop-down-timeout	60
hba0-connection-options	0: loop only 1: point-to-point(fabric)
hba0-device-configuration-mode	1: use port name

Parameters	Recommended settings
hba0-fc-tape	0
hba0-fc-data-rate	2: auto-negotiate
hba0-command-completion-option	1
persistent binding only option	0: reports the discovery of persistent bound and non-bound devices to the operating system

6

IBM TotalStorage SAN switches

An IBM SAN is a high-speed, interconnected fabric of centrally managed switches, multi-vendor heterogeneous servers, and storage systems. An IBM SAN can help companies derive greater value from their business information by enabling IT resource management and information sharing anytime, anywhere across the enterprise.

The various models of the IBM TotalStorage SAN Fibre Channel Switch 2109 and 3534-F08 provide Fibre Channel connectivity to a large variety of Fibre Channel attached servers and disk storage, including the IBM TotalStorage Enterprise Storage Server (ESS), FAStT Storage Servers, SAN Data Gateways for attachment of IBM Enterprise Tape systems 358x, and tape subsystems with native Fibre Channel connections.

In this chapter we provide details on these products and describe their interactions.

6.1 Overview

The IBM TotalStorage SAN Fibre Channel Switch interconnects multiple host servers with storage servers and devices to create a SAN. The switch can be used either as a standalone device to build a simple SAN fabric, or it can be interconnected with other switches to build a larger SAN fabric.

The interconnection of IBM and IBM-compatible switches and hubs creates a switched fabric containing several hundreds of Fibre Channel ports. The SAN fabric provides high performance, scalability, and fault tolerance required by the most demanding e-business applications and enterprise storage management applications, such as LAN-free backup, server-less backup, disk, and tape pooling, and data sharing.

The new IBM TotalStorage SAN Fibre Channel Switches operate up to 400 MB/s per port with full-duplex data transfer. Unlike hub-based Fibre Channel Arbitrated Loop (FC-AL) solutions, which reduce performance as devices are added, the SAN fabric performance increases as additional switches are interconnected.

> **SAN fabric:** This is an active, intelligent, and non-shared interconnection of multiple Fibre Channel switches, which increases the number of possible connections in the SAN. The fabric is also used to support fault tolerant fabric topologies, which eliminate single points of failure, and increases the maximum possible distance between interconnected devices. The high end industry standard supports up to seven consecutive switches (or hops) between two corresponding Fibre Channel devices. In a fabric environment, multi-stage or mesh topologies should be considered.

IBM offers four different models of switches which are OEM products from the Brocade SilkWorm family, as follows:

- The IBM TotalStorage SAN Fibre Channel Switch Model 3534-F08 is an 8-port model.
- The IBM TotalStorage SAN Fibre Channel Switch Model 2109-F16 is a 16-port model.
- The IBM TotalStorage SAN Fibre Channel Switch Model 2109-F32 is a 32-port model.
- The IBM TotalStorage SAN Fibre Channel Switch Model 2109-M12 is a (dual) 64-port model.

You may encounter these retired models of switches:

- The IBM TotalStorage SAN Fibre Channel Switch Model 2109-S08 is an 8-port model.

- The IBM TotalStorage SAN Fibre Channel Switch Model 2109-S16 is a 16-port model.

In the following sections, we describe the switches in greater detail with respect to their features, including high availability (HA), system components, zoning, inter-switch links (ISLs) and performance.

6.2 Product description

We describe the various product features in the sections that follow.

6.2.1 3534-F08

While the older IBM SAN Switches 2109-S08 and 2109-S16 supported ANSI standard Fibre Channel protocol at 1 Gb/s, all the new models are built upon a third-generation switch technology that supports a link bandwidth of 1 and 2 Gb/s. These third-generation or next-generation switches are often referred to as “2-Gb/s switches”.

The ports of all of the IBM SAN switches are numbered sequentially, starting with zero for the left-most port. The switch faceplate includes a silk screen imprint of the port numbers. With the 2 Gb/s switches, the ports are color-coded into quad-groups to indicate which ports can be used in the same ISL trunking group.

The 3534-F08, as shown in Figure 6-1, is an 8-port SAN switch. It supports Fibre Channel classes 2, 3, and F, and has a latency of less than 2 µs with no contention (assuming the destination port is free).

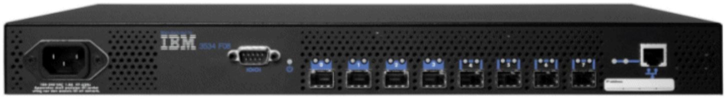


Figure 6-1 IBM SAN Fibre Channel Switch 3534-F08

Classes of service: Class F is a connectionless service for inter-switch control traffic. It provides notification of delivery or nondelivery between two E_Ports. Class 2 is a connectionless service between ports with notification of delivery or non-delivery. Class 3 is a connectionless service between ports without notification of delivery. Other than notification, the transmission and routing of Class 3 frames is the same as Class 2 frames.

The basic configuration of the 3534-F08 provides four SW-SFPs. In addition, a mixture of SW and LW ports can be configured by adding up to eight SFP transceivers. High availability is supported by hot-pluggable cooling fans and SFPs. An additional power supply can be ordered for redundancy.

The Entry Fabric switch configuration includes a fabric software license and connection to one other F08, and comes without the zoning feature. The Full Fabric upgrade option is needed to implement zoning. Web Tools is also included in the basic configuration.

Additional software features available are:

- Full Fabric Activation (feature code 7320)
- Performance Bundle (feature code 7321)
- Extended Fabric (feature code 7303)
- Remote Switch (feature code 7302).

For more information, 3534-F08 data sheets can be downloaded from:

```
http://www.storage.ibm.com/ibmsan/products/2109/library.html#support
```

6.2.2 2109-F16 and 2109-F32

The F16 and F32 are also built upon the third-generation switch technology that supports link bandwidth of 1 and 2 Gb/s.

The F16 is shown in Figure 6-2 and is a 16-port switch.

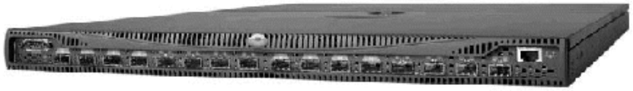


Figure 6-2 IBM SAN Fibre Channel Switch 2109-F16

The ports of all of the IBM SAN switches are numbered sequentially starting with zero for the left-most port. The switch faceplate includes a silk screen imprint of the port numbers. With the 2 Gb/s switches, the ports are color-coded into quad-groups to indicate which ports can be used in the same ISL trunking group.

The F16 consists of a system board with connectors for supporting up to 16 ports and a Fabric Operating System for building and managing a SAN fabric. The F16 supports Fibre Channel classes 2, 3 and F and has a latency of less than 2 µs with no contention (assuming the destination port is free).

The base model F16 configuration comes with eight SW or LW-SFPs. In addition, a mixture of SW and LW ports can be configured by adding up to sixteen SFP transceivers. High availability is supported by hot-pluggable cooling fans and SFPs, and an additional power supply can be ordered for redundancy.

Advanced Zoning and Web Tools is included in the F16 basic configuration.

Additional software features available are:

- Performance Bundle (f/c 7421)
- Extended Fabric (f/c 7303)
- Remote Switch (f/c 7302)
- Fabric Manager (f/c 7202)

The F32, as shown in Figure 6-3, is a 32-port switch that shares the same characteristics as the F16.

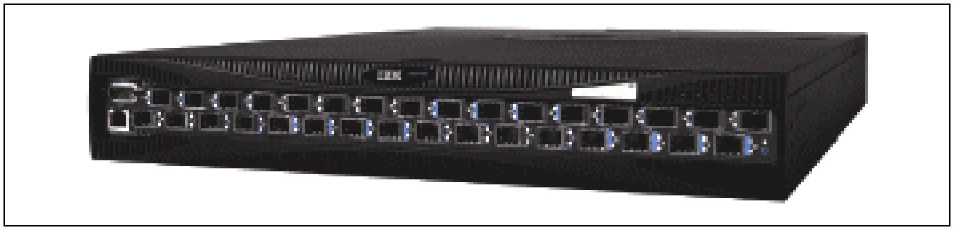


Figure 6-3 IBM SAN Fibre Channel Switch 2109-F32

The base model F32 configuration comes with 16 SW-SFPs. In addition, a mixture of SW and LW ports can be configured by adding up to sixteen SFP transceivers. High availability is supported by hot-pluggable cooling fans and SFPs. A redundant power supply enabling dual-power and non-disruptive power supply maintenance is included.

The Performance Bundle function, Advanced Zoning and Web Tools is also included in the F32 basic configuration.

Additional software features available are:

- Extended Fabric (f/c 7303 for F16, f/c 7503 for F32)
- Remote Switch (f/c 7302 for F16, f/c 7502 for F32)
- Fabric Manager (f/c 7202)

For more information, the F16 and F32 data sheets can be downloaded from:

`http://www.storage.ibm.com/ibmsan/products/2109/library.html#support`

6.2.3 2109-M12

The M12 is a bladed architecture, it consists of two logical 64-port switches in one chassis. Each logical switch has its own:

- Unique domain ID
- Switch World Wide Name (WWN)
- IP address

Both logical switches share:

- Chassis
- Four hot swappable, redundant power supplies:
  - Any two are needed to provide power for a maximum configuration
  - Selective power down of cards (configurable) when only one power supply is working
  - Two AC connectors
- Three hot swappable, redundant fans
  - Any two needed to cool the entire switch
  - One fan can keep the unit running for about one hour
- Dual control processor (CP) operates in active/standby mode

The M12 is shown in Figure 6-4.

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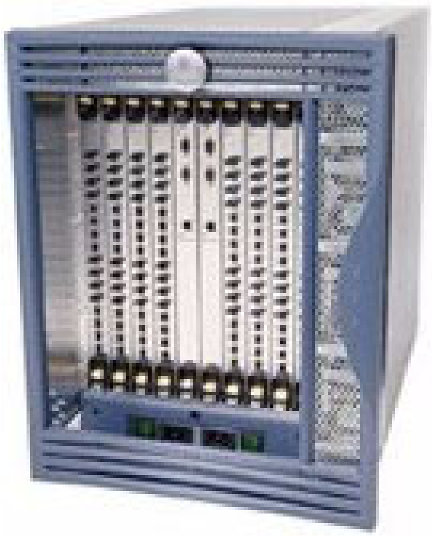


Figure 6-4 2109-M12

The switch layout is shown in Figure 6-5.

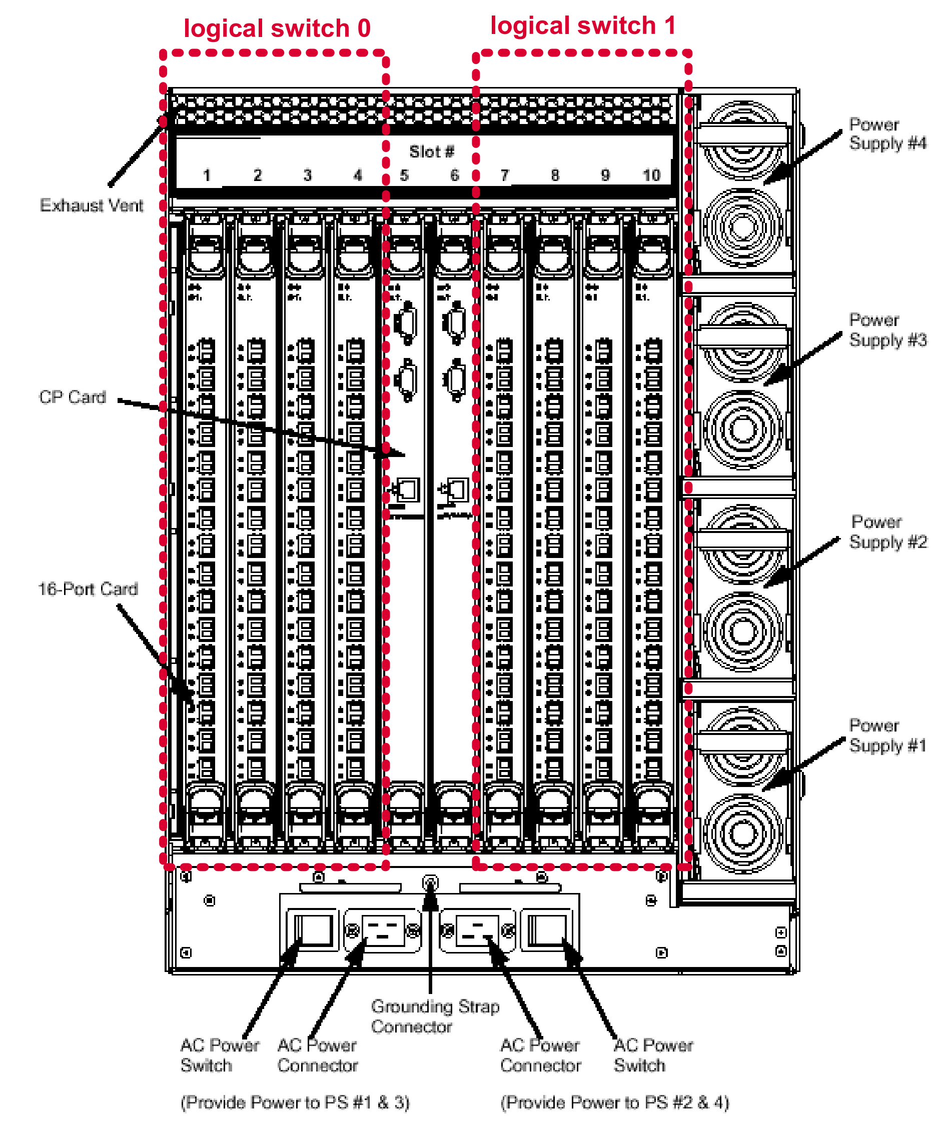


Figure 6-5 Port side of the 2109-M12

Each of the logical switches supports up to four, 16-port Fibre Channel modules (blades) enabling 64 universal (E, F, and FL ports), full duplex, ports. Each port is capable of self-negotiation to the highest speed supported by the attached SAN device. Two CP cards are located in the middle of the chassis, “logical switch 0” occupies blades from slot 1 to 4, “logical switch 1” from 7 to 10.

The chassis holds two redundant hot-swappable CP cards in slots 5 and 6, providing a modem serial port, a terminal serial port, and a 10/100 Mb/s Ethernet port.

Switches and processors are de-coupled, meaning one CP card is active, the other one is in standby mode. The active CP manages both logical switches and only the active CP card controls the M12. If the active CP card fails or is removed, the standby CP card automatically becomes the active CP card. Failover occurs as soon as the active CP card is detected as faulty or is removed.

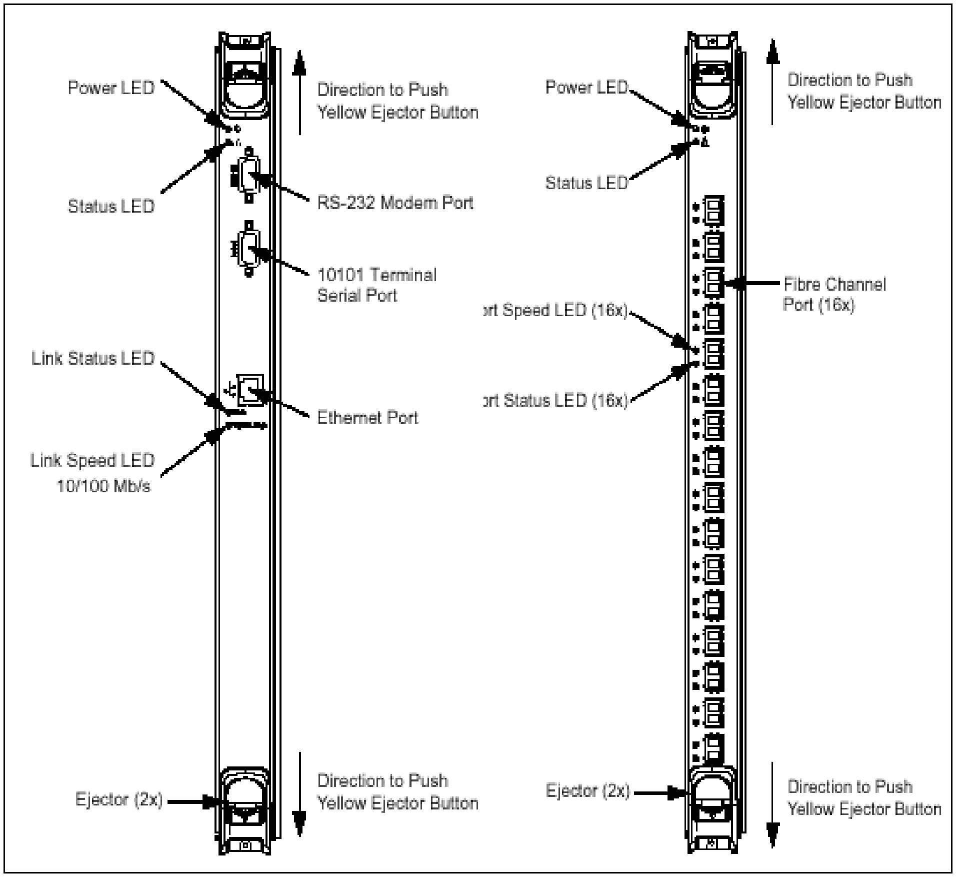


Figure 6-6 CP (left) and Fibre Channel Module (right)

The port blades consist of 16 ports providing SFP transceivers. The same advanced ASIC technology introduced in the Fxx models is used in the M12.

M12 port numbering scheme

Physical port numbering for each port card begins with port 0 at the bottom, and port 15 at the top of the card, as shown in Figure 6-7.

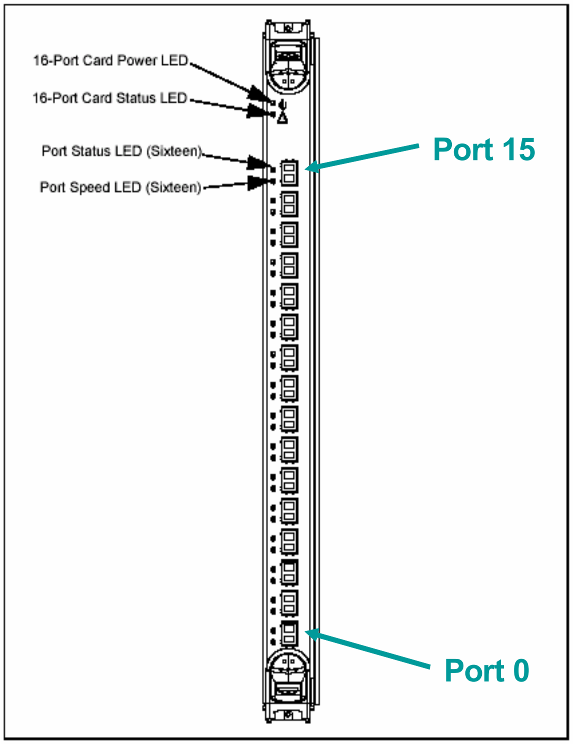


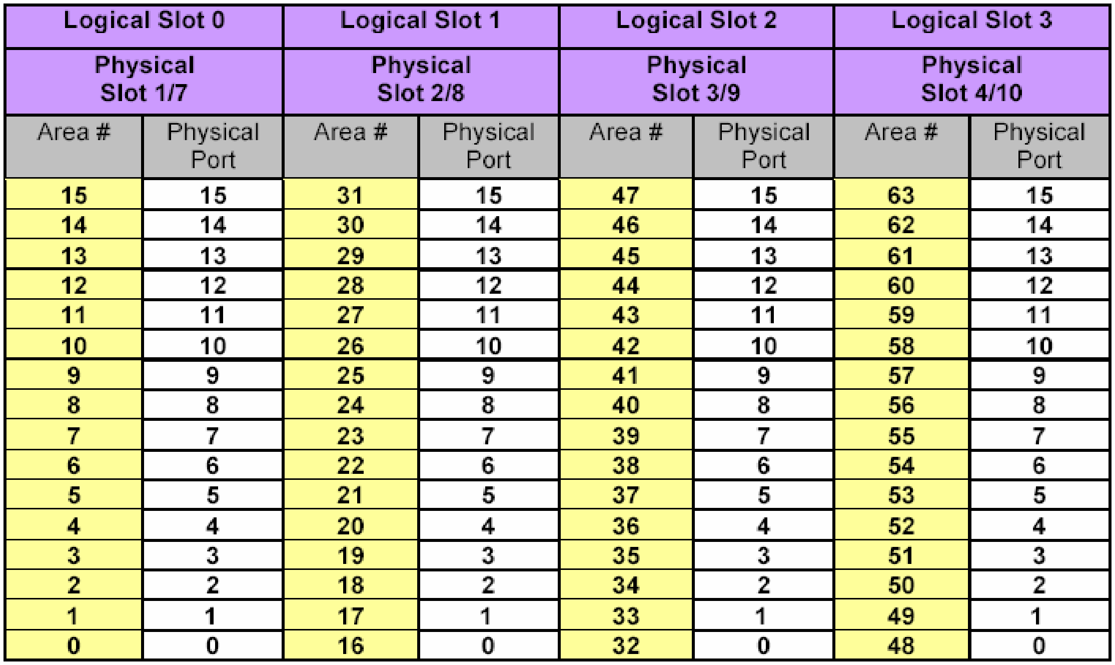
Figure 6-7 Physical port numbering

Because each logical switch can have up to 64 ports, it is necessary to number these ports from a switch perspective, not just at a blade level. This switch port numbering is known as port area (sometimes referred to as the absolute port number) or area, numbering the ports for each logical switch from area 0 through 63.

Using the command line interface (CLI), zoning commands use the port area numbering, while other commands require the slot/port method.

The table in Figure 6-8 shows the *area* number for each physical port location:

- The Physical Slot number refers to the logical switch 0 / logical switch 1 slot position.
- The Logical Slot numbering is only used to help define the FC address.



Logical Slot 0		Logical Slot 1		Logical Slot 2		Logical Slot 3	
Physical Slot 1/7		Physical Slot 2/8		Physical Slot 3/9		Physical Slot 4/10	
Area #	Physical Port	Area #	Physical Port	Area #	Physical Port	Area #	Physical Port
15	15	31	15	47	15	63	15
14	14	30	14	46	14	62	14
13	13	29	13	45	13	61	13
12	12	28	12	44	12	60	12
11	11	27	11	43	11	59	11
10	10	26	10	42	10	58	10
9	9	25	9	41	9	57	9
8	8	24	8	40	8	56	8
7	7	23	7	39	7	55	7
6	6	22	6	38	6	54	6
5	5	21	5	37	5	53	5
4	4	20	4	36	4	52	4
3	3	19	3	35	3	51	3
2	2	18	2	34	2	50	2
1	1	17	1	33	1	49	1
0	0	16	0	32	0	48	0

Figure 6-8 Physical port location to area numbering cross reference

The M12 accommodates two logical 64-port switches in one chassis. In order to form a 128-port fabric, both logical switches have to be connected by one or more external ISLs. For critical applications and high availability, it is not recommended to use the dual switches in a single chassis as redundant fabrics or redundant core, since there is still the potential for a single point of failure.

The base configuration provides an IBM rack fully equipped with power supplies and fans. It includes two CP cards and two FC cards holding 32 SFP either SW or LW, to form a 32-port switch. The basic software license comes with:

- WebTools
- Advanced Zoning
- Fabric Watch
- Performance Bundle:
  - ISL Trunking
  - Global Performance Monitoring

Additional software features available are:

- Extended Fabric Activation (f/c 7603)
- Remote Switch Activation (f/c 7602)
- Fabric Manager (f/c 7201)

For the model M12, the chassis-WWN is used to license all the software products. The QuickLoop feature is not supported directly by the M12 switches, but private loop devices may be attached to QuickLoop-capable switches in this fabric.

For more information, the M12 data sheets can be downloaded from:

```
http://www.storage.ibm.com/ibmsan/products/2109/library.html#support
```

6.3 Switch components

Next we describe some components that are integral to the switches.

System board

All IBM switch models except the M12 carry a systems board enclosed in an air-cooled chassis that is mounted in a standard rack or used as a stand-alone unit. The board contains a system processor, an integrated memory controller, a bridged dual PCI bus, and an I^2C controller. The I^2C bus provides peripheral I/O control for the LCD module, thermometers, general I/O functions, and others. In addition, the design includes an RS232 serial port, 10/100 BaseT Ethernet port, SDRAM, and FLASH EEPROM for firmware text, initialized data, and switch configuration information. The M12 CP card (as shown in Figure 6-6 on page 192) has the same internal structure, except that it is a replaceable module in the M12-chassis. The system processor of the F08 and F16 is an Intel 80960VH clocked with 100 Mhz, The system processor of the F32 and M12 CP card is an IBM PowerPC® 405GP clocked with 200 Mhz.

Central memory module

The switch is based on a central memory architecture and has a central memory module (CMM). In this scheme, a set of buffers in the central memory is assigned to each port, to be used for the receipt of frames. As an ASIC port receives and validates a frame, it stores the frame in one of its receive buffers in the central memory and forwards a routing request (“Put” message) to the appropriate destination ports. When a destination port is capable of transmitting the frame, it reads the frame contents from central memory and forwards the frame to its transmit interface. It does not wait for the frame to be written in memory, unless the port is busy. Once it has removed an entry for a frame from its internal transmit queue in preparation for frame transmission, the destination port sends a “Finish” message to indicate “transmission complete” to the port that received the frame, allowing the receiving port to reuse the buffer for subsequent frames to be received.

The switch central memory is incorporated into the ASICs. Frames received on the eight ports in an ASIC are written into a portion of central memory in the receiving chip; received frames may not be written into the sections of central memory located in other ASICs. All transmitters in a switch may read from the memories in any of the ASICs.

Third generation ASIC

The new generation ASIC is a BLOOM ASIC, and it provides twice as many ports as its predecessor ASIC, called LOOM. So, eight Fibre Channel ports can be used to connect to external N_Ports (as an F_Port), external loop devices (as an FL_/L_Port), or to other switches (as an E_Port). Each port operates at up to 2.125 Gb/s. The ASIC contains the Fibre Channel interface logic, message/buffer queuing logic, receive buffer memory for the eight on-chip ports, and other support logic.

Buffers

Inside each ASIC, there are a total of 224 receive buffers that accommodate full 2112-byte payload frames for eight ports (or 256 2048-byte frames). Each memory block is accessed in a time-sliced fashion. The buffer design is efficient in that if frames are smaller than 2112 bytes, the buffer pool will expand proportionately providing effectively greater than 256 receive buffers. A single eight port ASIC can buffer a total of 896 “small” frames (36-576 bytes), and this is enabled using mini-buffers of 308 bytes in size.

The buffer-to-buffer credit for each F/FL_Port can be up to 31. Credit for a port in E_Port mode can be a total of 31 distributed among 8 virtual channels. However, the switch buffer sharing scheme provides more effective buffer utilization when the advertised buffer-to-buffer credit of each port is a smaller number, allowing the pool of buffers to be shared between ports.

Control message interface

The IBM SAN Fibre Channel Switch control message interface (CMI) consists of a set of control signals used to pass hardware-level messages between ports. These control signals are used by recipient ports to inform transmitting ports when a new frame is to be added to the transmitter’s output queue. Transmitting ports also use the CMI to inform recipient ports that a frame transmission has been completed. A recipient port is free to reuse a receive buffer when it receives notification that the frame has been transmitted. Multiple notifications are required, in the case of multicast, to determine when a receive buffer is freed.

The CMI interfaces for the ASICs are connected inside each ASIC through a message crossbar, implementing a “barrel shift” message scheme. Each chip time-shares its output port to each possible destination chip in the switch. If it has a message to send to a particular destination during the corresponding timeslot, the chip will use the timeslot to send the message; otherwise, the output port lines will be driven to indicate no message is present.

The timesharing of the output CMI control signals of the ASICs are arranged out of phase from each other, such that, in any given clock cycle, each chip's output port is time-shared to a different destination chip. Thus, messages appearing at the input control signal interface of a given ASIC are also time-shared through each possible source chip in the switch.

6.3.1 GBIC modules

In the 1 Gb/s switch models GBIC modules are either shortwave (SW) or longwave (LW) fiber optics.

The shortest supported optical cable length is 2 m. Using shorter cables could exceed the expected signal output at the optical GBIC and is not recommended according to the Fibre Channel standards.

With SW GBICs, cable lengths can be 200 m (with 62.5 µm multi-mode fiber cable) or 500 m (with 50 µm multi-mode fiber optic cable). With LW GBICs, single-mode fiber optic cable lengths of up to 10 km are supported.

For more information on GBICs, refer to 2.2.2, "Gigabit Interface Converters" on page 23.

6.3.2 SFP modules

Nowadays, IBM TotalStorage SAN switches accommodate SFP modules instead of GBICs. The SFP modules supported are the shortwave (SW) and longwave (LW) fiber optics.

With SW SFPs, cable lengths can be 300 m at 2 Gb/s and up to 500 m at 1 Gb/s using 50 µm multi-mode fiber cable. With LW SFPs, single-mode fiber cable lengths of up to 10 km are supported.

For more information on SFPs, refer to 2.2.1, "Small Form Factor Optical Transceivers" on page 21.

6.3.3 Serial port connection

The serial port is provided in all of the switches for recovery from loss of password, gathering information for debugging purposes, recovering factory settings and for the initial configuration of the IP address for the switch. It is not intended to be used for normal administration functions. The serial is a standard DB-9 socket.

To connect the serial port to PC: Configure your Windows terminal emulation to:

9600 baud, 8 data bits, no parity, 1 stop bit, with **no flow control**.

To connect the serial port to UNIX: Enter the following string at the prompt:

```
tip /dev/ttyb -9600
```

6.3.4 Ethernet connection

All of the switches provide a 10/100BaseT Ethernet port for the switch management console interface. This allows access to the switch's internal SNMP agent, and also allows remote Telnet and Web access for remote monitoring and configuring. The Ethernet port provides a standard RJ-45 socket. Each new IBM SAN switch has the identical predefined IP address of 10.77.77.77, which may be changed before connecting a new switch to a fabric.

Note: The IP address may be changed using the Ethernet Port. But you have to keep this in mind: Misconfiguration of the IP address will cut off the Ethernet connection to the switch — you will then need to connect to the switch via the serial port connection to correct the IP address.

6.4 Fabric Operating System

The Fabric Operating System (Fabric OS) — often referred to as the switch firmware — is a real-time operating system that provides the core infrastructure needed by growing businesses to deploy scalable and robust Storage Area Networks (SANs). Fabric OS runs on the IBM SAN Fibre Channel switches and supports scalable SAN fabrics of thousands of interconnected devices while ensuring high-performance data transfer among connected resources and servers.

Fabric OS easily manages both large switch fabrics and small department Fibre Channel Arbitrated Loop (FC-AL) configurations. Moreover, Fabric OS is highly flexible, making it easy for network administrators to add functionality and scale their SANs at the speed of business.

6.4.1 Reliable data services

Fabric OS data services deliver high-speed data transfer among hosts and storage devices. Fabric OS data services include:

- **Universal port support for flexible fabric architectures:** Fabric OS identifies port types and initializes each connection specific to the attached Fibre Channel system, whether it is another switch, host, private loop, or fabric-aware target system.
- **Self-discovery of new devices by the fabric:** Automatically discovers and registers new devices as they are connected.
- **Continuous monitoring of port for exception conditions:** Disables data transfer to ports when they fail, such as when there is a loss of reliable communications on a link. The port is automatically re-enabled when the exception condition has been corrected, minimizing impact to production systems not experiencing exceptions.
- **Zoning:** Limits access to data by segmenting the fabric into virtual private storage area networks. With the IBM SAN Switch -F and -M models, zoning has been developed further and is known as Advanced Zoning available on 2 Gb/s platforms, featuring third-generation ASIC.

6.4.2 Services based on standards

Fabric OS provides a standard set of Fibre Channel services that provide fault resiliency and automatic reconfiguration when a new switch is introduced. These services include:

- **Management Server:** Supports in-band discovery of fabric elements and topology.
- **Simple Name Server (SNS):** Incorporates the latest Fibre Channel standards. SNS registers information about SAN hosts and storage devices. It also provides a Registered State Change Notification when a device state changes or a new devices introduced.
- **Alias Server:** Supports the Multicast Service that broadcasts data to all members of a group.

6.4.3 Support for private loop configurations

Because older storage devices were designed for FC-AL configurations, a standard Fabric OS facility known as translative mode, provides a mechanism to support private-loop devices. The fabric registers them, which enables hosts to access **private storage devices** as if they were public devices. In addition, optional QuickLoop feature provides support for private-loop **servers** in a fabric.

6.4.4 Routing services for high availability

Fabric OS provides dynamic routing services for high availability and maximum performance. Fabric OS routing services include:

- **Dynamic path selection using Link State Protocols:** Uses Fabric Shortest Path First **(**FSPF**)** to select the most efficient route for transferring data in a multi-switch environment.
- **Load sharing to optimize throughput through inter-switch links (ISLs):** Supports high throughput by using multiple ISLs between switches.
- **Load balancing to maximize throughput through ISLs:** Supports even higher throughput by bundling multiple inter-switch links (ISLs) between switches.
- **Automatic path failover:** Automatically reconfigures alternate paths when a link fails. Fabric OS distributes the new configuration fabric-wide and re-routes traffic without manual intervention.
- **In-order frame delivery:** Guarantees that frames arrive in order.
- **Automatic re-routing of frames when a fault occurs:** Re-routes traffic to alternative paths in the fabric without interruption of service or loss of data.
- **Routing support by link costs:** Lets SAN administrators manually configure the link costs of individual ISLs to create custom FSPF functionality that support each business’ unique SAN fabric management objectives.
- **Support for high-priority protocol frames:** Useful for clustering applications,; ensures that frames identified as priority frames receive priority routing to minimize latency.
- **Static routing support:** Allows SAN administrators to configure fixed routes for some data traffic and ensure resiliency during a link failure.
- **Automatic reconfiguration:** Automatically re-routes data traffic onto new ISLs when they are added to the SAN fabric.

6.4.5 Management interfaces

Fabric OS includes an extensive set of facilities for end-to-end SAN management, including:

- **Management server based on FC-GS-3:** Permits in-band access to fabric discovery.
- **SNMP management services:** This category includes services such as:
  - An SNMP agent and a series of comprehensive Management Information Bases (MIBs). Assists with monitoring and configuring the switches.

  - An extensive set of trap conditions. Immediately alerts administration about critical exception conditions.
  - In-band (IP over the Fibre Channel link) or out-band (IP over Ethernet interface). Gathers SNMP information and provides access to all the switches in the fabric through a single fabric connection.

- **Syslog daemon interface:** Directs exception messages to up to six recipients for comprehensive integration into a host-based management infrastructure.
- **Switch beaconing:** Helps to identify an individual switch among a group of others.
- **Loop diagnostic facilities:** Assists in fault-isolation for loop-attached devices.
- **Command Line interface (CLI):** Provides an easy-to-use management system via serial port or Ethernet interface.
- **Web Tools (also called StorWatch Switch Specialist):** Allows SAN administrators to monitor and manage SAN fabrics using a Java-capable Web browser from standard desktop workstations
- **SCSI-3 Enclosure Services-bundled fabric software (SES):** Enables management without implementing IP.

6.4.6 Switch upgrade

The ability to upgrade switches efficiently is important for testing new Fabric OS within specific environments. Because a network of switches can provide alternate paths within a SAN, path failure is handled transparent to applications, and administrators can upgrade switches in the network without interrupting operations. Upgrades on switches with device connections are performed in conjunction with the dual-path capabilities of servers and storage. However, with the switch “fastboot” option, failover is often transparent to any server-based failover software, depending on delays configured into the software.

Fabric OS download

After an administrator has tested the new Fabric OS, it can be downloaded to other portions of the SAN. The ability to upgrade selected parts of the network or run different OS versions within the SAN is a key advantage over single monolithic switch designs. For instance, a particular capability or fix for a device might need to be loaded onto only the applicable switch. Also, switch resellers often standardize into a particular version of switch OS. As the SAN grows, it might include switches from many different resellers. As a result, administrators have the choice of continuing to use the supported Fabric OS versions on particular switches instead of being forced to upgrade the entire system.

2109 Fabic OS can be downloaded from the Web via:

`http://www.storage.ibm.com/ibmsan/products/2109/library.html#support`

6.5 Advanced Security

As organizations grow their SANs and connect them over longer distances through existing networks, they have an even greater need to effectively manage SAN security and policy requirements. To help these organizations improve security, Advanced Security (AS) provides a comprehensive security solution for IBM-based SAN fabrics. With its flexible design it enables organizations to customize SAN security in order to meet specific policy requirements. In addition, it works with a security practice which is already deployed in many SAN environments: Advanced Zoning.

The most complete solution for securing SAN infrastructures, AS provides following features to Fabric OS:

- Fabric Configuration Servers (FCS, *trusted switches*)
- Management Access Controls (MAC)
- Device Connection Controls (DCC)
- Switch Connection Controls (SCC)
- Secure Management Communications

These features will be used in a structured way by defining through the Fabric Management Policy Set (FMPS). It specifies access controls to apply to the fabric management capabilities and the physical connections and components within the fabric. FMPS handles several different types of policies, each with different aspects. The policies provide control over management access to the fabric. Together with the potential points of vulnerability of fabric devices identified in 3.8.2, “Vulnerabilities” on page 116, organizations use FMPS to define their security requirements for a fabric by establishing a set of security domains. These domains typically define different categories of communications that must be protected by the fabric security architecture. These domains include:

Host-to-Switch Domain

In host-to-switch communications, individual device ports are bound to a set of one or more switch ports using Access Control Lists (ACLs). Device ports are specified by WWN and typically represent HBAs. The AS OS DCC feature enables binding by WWN (port) and ACL to secure the host-to-switch connection for both normal operations and management functions.

Administrator-to-Security Management Domain

Because security management impacts the security policy and configuration of the entire SAN fabric, administrator access controls work in conjunction with security management functions. In addition, administrator-level fabric password access provides primary control over security configurations.

Security Management-to-Fabric Domain

AS secures certain elements of the management communications — such as passwords — on some interfaces between the security management function and a switch fabric. The security management function encrypts appropriate data elements (along with a random number) with the switch's public key. The switch then decrypts the data element with its private key. For more information about public and private keys, see "Encryption" on page 119.

Switch-to-Switch Domain

In secure switch-to-switch communications, the switches enforce security policy. The security management function initializes switches by using digital certificates and ACLs. Prior to establishing any communications, switches exchange these credentials during mutual authentication. This practice ensures that only authenticated and authorized switches can join as members of the SAN fabric or a specific fabric zone. This authentication process prevents an unauthorized switch from attaching to the fabric through an E_Port.

6.5.1 Fabric configuration servers

Fabric Configuration Servers are *trusted* SAN switches responsible for managing the configuration and security parameters (including zoning) of all other switches in the fabric. Any number of switches within a fabric can be designated as Fabric Configuration Servers as specified by WWN, and the list of designated switches is known fabric-wide.

As part of the security policy configuration process, organizations select a primary Fabric Configuration Server and potential backup servers. Among these, only the primary Fabric Configuration Server can initiate fabric wide management changes, and all initiation requests must be identified to ensure fabric security: a capability that helps eliminate unidentified local management requests initiated from subordinate switches.

6.5.2 Management access controls

Management Access Controls enable organizations to restrict management service access to a specific set of end points: either IP addresses (for SNMP, Telnet, HTTP, or API access), device ports (for in-band methods such as SES or Management Server), or switch WWNs (for serial port and front-panel access).

Disabling front-panel access of the older S16 switch prevents unauthorized users from manually changing fabric settings.

IBM TotalStorage SAN switches enable secure IP-based management communications (like SSL) between a switch and Web Tools. Elements of the manager-to-switch-communications process, such as passwords, are encrypted to increase security.

The M12 also provides secure Telnet access through SSH Secure Shell, a network security protocol that helps ensure secure remote login and other network services over insecure networks.

6.5.3 Device connection controls

Device connection controls, also known as WWN Access Control Lists (ACLs) or Port ACLs, enable organizations to bind an individual device port to a set of one or more switch ports. Device ports are specified by WWN and typically represent HBAs. These controls secure the server-to-fabric connection for both normal operations and management functions.

By binding a specific WWN to a specific switch port or set of ports, device connection controls can prevent a port in another physical location from assuming the identity of a real WWN. This capability enables better control over shared switch environments by allowing only a set of predefined WWNs to access particular ports in the fabric.

6.5.4 Switch connection controls

Switch connection controls enable organizations to restrict fabric connections to a designated set of switches, as identified by WWN. When a new switch is connected to a switch that is already part of the fabric, the two switches must be mutually authenticated. As a result, each switch must have a digital certificate and a unique public/private key pair to enable truly authenticated switch-to-switch connectivity.

New switches receive digital certificates at the time of manufacture. However, organizations with existing switches will need to upgrade them with certificate and key information at the installed location.

Switch-to-switch operations are managed in-band, so no IP communication is required. This capability prevents users from arbitrarily adding switches to a fabric. Any new switch must have a valid certificate and also appear in the fabric-authorized switch ACL. Digital certificates ensure that the switch name (which is the WWN) is authentic and has not been modified.

6.5.5 Fibre Channel Authentication Protocol

The Switch Link Authentication Protocol (SLAP/FC-SW-3), establishes a region of trust between switches. For an end-to-end solution to be effective, this region of trust must extend throughout the SAN, which requires the participation of fabric-connected devices, such as HBAs. The joint initiative between Brocade and Emulex establishes Fibre Channel Authentication Protocol (FCAP) as the next-generation implementation of SLAP. Customers gain the assurance that a region of trust extends over the entire domain.

FCAP has been incorporated into its fabric switch architecture and has proposed the specification as a standard to ANSI T11 (as part of FC-SP). FCAP is a Public Key Infrastructure (PKI)-based cryptographic authentication mechanism for establishing a common region of trust among the various entities (such as switches and HBAs) in a SAN. A central, trusted third party serves as a guarantor to establish this trust. With FCAP, certificate exchange takes place among the switches and edge devices in the fabric to create a region of trust consisting of switches and HBAs.

Because a network is only as secure as its weakest link, all switches in the fabric must support AS in order to achieve the highest level of security fabric-wide.

Advanced Security is covered in more depth in the IBM Redpaper:

- *Advanced Security in an IBM SAN*, REDP3726

Details of how to implement Advanced Security can be found in this edition of the IBM Redbook:

- *Implementing an Open IBM SAN,* SG24-6116-03

6.6 Licensed features

All the licensed features can be factory-installed or added later. No additional software installation is required. Instead, the feature has to be activated by an activation key process.

Fabric Watch

Fabric Watch enables switches to continuously monitor the health of the fabrics, watching for potential faults based on defined thresholds for fabric elements and events, so making it easy to quickly identify and escalate potential problems. It monitors each element for out-of-boundary values or counters and provides notification to SAN administrators when any exceed the defined boundaries. SAN administrators can configure which elements, such as error, status, and performance counters within a switch, are monitored.

Fabric Manager

Fabric Manager provides a Java-based application that can simplify management of a multiple switch fabric. Web Tools and Fabric Manager run on the same management server attached to any switch in the fabric. It may manage up to eight fabrics. Fabric Manager requires a Windows NT/2K or Solaris 7 server with a Netscape or Internet Explorer Web browser.

Remote Switch

The Remote Switch feature is used on two switches that are interconnected with a pair of ATM/WAN gateways, providing for Fibre Channel to be tunneled over a non-Fibre Channel path.

Extended Fabric

The Extended Fabric feature provides extensions within the internal switch buffers. This maintains performance with distances greater than 10 km, and up to 120 km, by maximizing buffering between the selected switch interconnect links.

Performance Bundle

The Performance Bundle feature provides both ISL Trunking and Advanced Performance Monitoring capabilities. The ISL Trunking feature enables Fibre Channel packets to be distributed across up to four bundled ISL connections between two switches providing up to 8 Gb/s of bandwidth and preserving in-order delivery. Both interconnected switches must have this feature activated.

Advanced Performance Monitoring provides SAN performance management through an end-to-end monitoring system. If your fabric includes 1 Gb/s switches, you can take advantage of the end-to-end performance monitoring features by installing a 2 Gb/s switch (that has that feature activated) anywhere in the path between the source and destination port.

QuickLoop

QuickLoop runs on the IBM TotalStorage SAN Fibre Channel switches except the M12. It is a unique feature that combines arbitrated loop and fabric topologies, and complies with FC-AL standards. Because this feature allows servers which only support private loop to be attached to fabrics, it can best be described as a Private Loop Fabric Attach (PLFA), as compared to a Private Loop Direct Attach (PLDA).

6.7 IBM TotalStorage fabric features

In the topics that follow we describe some of the features that the 2109 switches and fabrics share. Most of these are features which are vendor unique and are areas for comparison when deciding upon a solution.

6.7.1 Blocking versus non-blocking

The 2109 is a non-blocking implementation. This means any two pairs of ports can be active and transferring data without blocking transfer of data from another pair of ports.

Each port is allocated a time slice to transfer data, and cut through routing occurs that allows for immediate transfer of data from an input port to an output port if that port is free. Blocking occurs in a fabric design with multiple switches when data from multiple sources must be sent to a single destination port, or when data is required to be sent across an ISL from multiple input ports. Data is blocked, that is to say, buffered in the switch, and sent to the destination port based on the priority set of the data (default priority for data based on virtual channels gives greater priority to F_Port traffic on ISLs than data traffic). The nature of Fibre Channel is that data is transferred based on buffer credits assigned to ports and sending and receiving devices manage the credits so that there is never an overrun of data in the switch.

6.7.2 Supported fabric port types

The 2109 dynamically assigns one of the following types to its ports depending on the port function or status:

- **E_Port:** This is an expansion port. A port is designated an E_Port when it is used as an inter-switch expansion port to connect to the E_Port of another switch, to enlarge the switch fabric.
- **F_Port:** This is a fabric port that is not loop capable. It is used to connect an N_Port point-to-point to a switch.
- **FL_Port:** This is a fabric port that is loop capable. It is used to connect NL_Ports to the switch in a public loop configuration.
- **G_Port:** This is a generic port that can operate as either an E_Port or an F_Port. A port is defined as a G_Port after it is connected but has not received response to *loop* initialization or has not yet completed the *link* initialization procedure with the adjacent Fiber Channel device.
- **L_Port:** This is a loop capable port. It connects NL_Ports, which support private loop configuration only.

- **U_Port:** This is a universal port, even a more generic switch port than a G_Port. It can operate as either an E_Port, F_Port, or FL_Port. A port is defined as a U_Port when it is not connected or has not yet assumed a specific function in the fabric.

6.7.3 Supported node port types

- **N_Port:** This is a node port that is not loop capable. It is used to connect an equipment port to the fabric.
- **NL_Port:** This is a node port that is loop capable. It is used to connect an equipment port to the fabric in a loop configuration through an L_Port or FL_Port.

Figure 6-9 shows the different Fibre Channel port types.

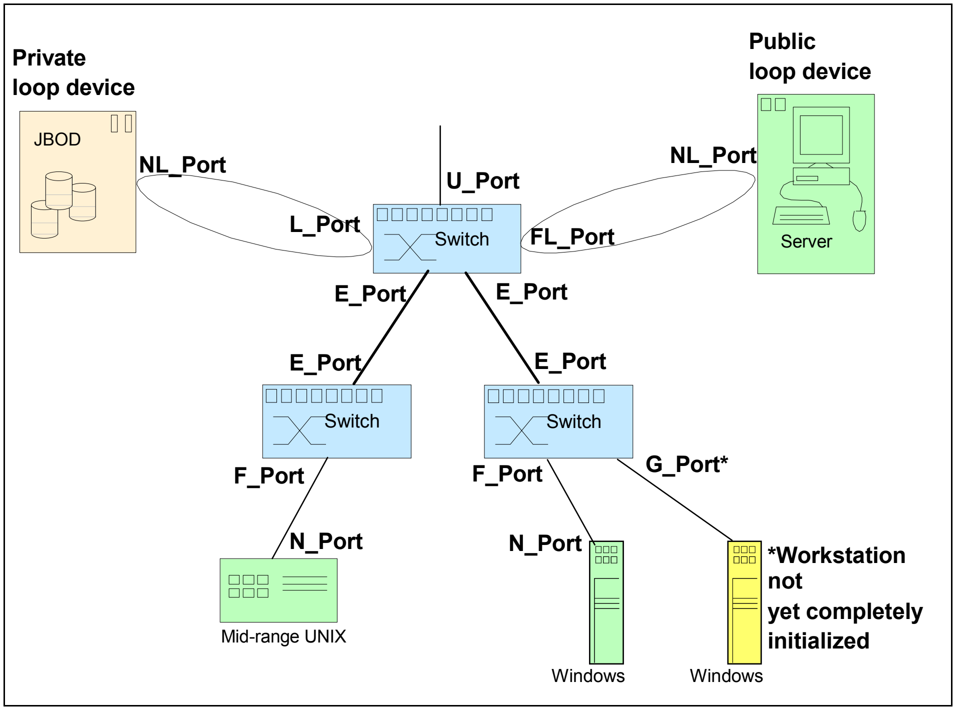


Figure 6-9 Fibre Channel port types

6.8 ISL

Although redundancy provides an excellent way to enhance availability, it does not protect against all types of outages. Just as companies have embraced client/server networking to overcome the limitations of the mainframe-centric IT infrastructure, many are taking a similar approach to SANs. A networked SAN is a flexible architecture that can be easily implemented and quickly adapted to changing requirements — extending the availability characteristics of hardware and software components into the SAN fabric itself.

To build a SAN network, switches need to be connected by inter-switch links (ISL). An ISL is created simply by connecting two switches with a fiber optic cable. Both switch ports turn immediately into E_Ports, and the switch automatically discovers connected switches and creates the FSPF routing table used by the entire fabric. No programming of the fabric is necessary, as the FSPF table will be updated as new switches join in.

The network can be scaled from the number of ports needed at the edge, as well as being scaled at the core switch level, to provide higher bandwidth and redundant connectivity. In fact, SAN fabrics can feature multiple levels of availability, including meshed tree topologies of switches, single fabrics with dual connectivity, and dual fabrics with dual connectivity for environments that require the highest levels of availability

Switch interoperability: The 2109s are all interoperable with each other. A fabric can be built with a mix of different switch models. For more information, refer to Section 6.11, “Multi-Vendor interpretability” on page 229.

6.8.1 ISLs without trunking

ISLs provide for connection between switches. Any switch in the fabric can have one or more links to another switch in the fabric. At switch start-up, these links are initialized and at fabric login of the Fibre Channel devices, these ISLs are allocated in a round-robin fashion to share the load on the system. The switch guarantees in-order delivery, however, it means that if one Fibre Channel device loads up its dedicated ISL highly and for lengthy periods of time, a second device dedicated to this very ISL may not get all of its data through, as shown in Figure 6-10.

At the same time, a parallel ISL that is dedicated to another Fibre Channel device may be idle.

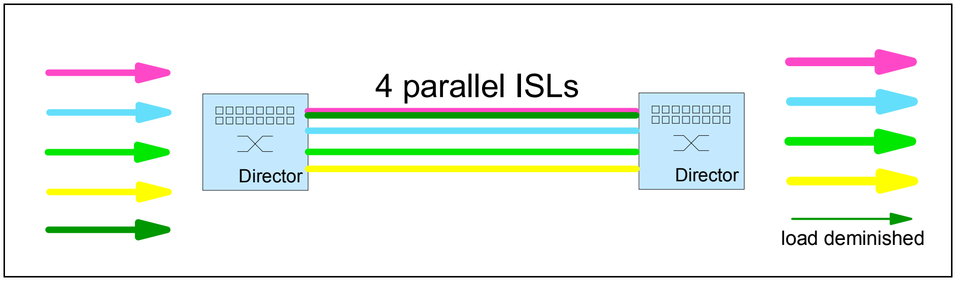


Figure 6-10 Parallel ISLs without trunking

However, there are some features that can be used to increase inter-switch bandwidth:

- Adding an ISL between switches is dynamic and can be done while the switch is active. Adding a new ISL will result in a routing re-computation and new allocation of ISL links between source and destination ports. Similarly, removing a link will result in FSPF routing re-computation across the fabric and possible fabric re-configuration.
- Adding ISLs will cause routing traffic/zoning data to be updated across the fabic via a spanning tree. The total number of ISLs is not so relevant as the amount of configuration changing, as each change will result in a re-calculation of routes in the fabric. When numerous fabric reconfigurations occur (removing or adding links, rebooting a switch, and so on) the load on the switches CPUs will be increased and some fabric events may time-out waiting on CPU response. This occurs only during fabric reconfiguration activities and does affect frame traffic per se, only tasks that require use of the CPU (no CPU intervention is required for normal frame routing, this is all done by switch hardware).
- No more than eight ISLs between any two switches is supported. More than eight ports can be used on a switch for ISL traffic as long as no more than eight go to a single adjacent switch.

Note: A spanning tree connects all switches from the so called principal switch to all subordinate switches. This tree spans in a way such that each switch (or leaf of the tree) is connected to other switches, even if there is more than one ISL between them - that is to say, there are no loops.

6.8.2 ISLs with trunking

It is possible that there are drawbacks in using parallel ISLs as this was implemented with the 1 Gb/s switches. With the 2 Gb/s switches, there is an optional feature called ISL Trunking. Trunking is ideal for optimizing performance and simplifying the management of a multi-switch SAN fabric.

When two, three, or four adjacent ISLs are used to connect two switches, the switches automatically group the ISLs into a single logical ISL, or trunk. The throughput of the resulting trunk is 4, 6, or 8 Gb/s.

ISL trunking is designed to significantly reduce traffic congestion. As shown in Figure 6-11, four ISLs are combined into a single logical ISL with a total bandwidth of 8 Gb/s. It can support any number of devices. Figure 6-11 simplifies the case by showing five exchanges at a time over four ISLs.

To balance the load across all of the ISLs in the trunk, each incoming frame is sent across the first available physical ISL in the trunk. As a result, transient workload peaks for one system or application are much less likely to impact the performance of other devices of the SAN fabric.

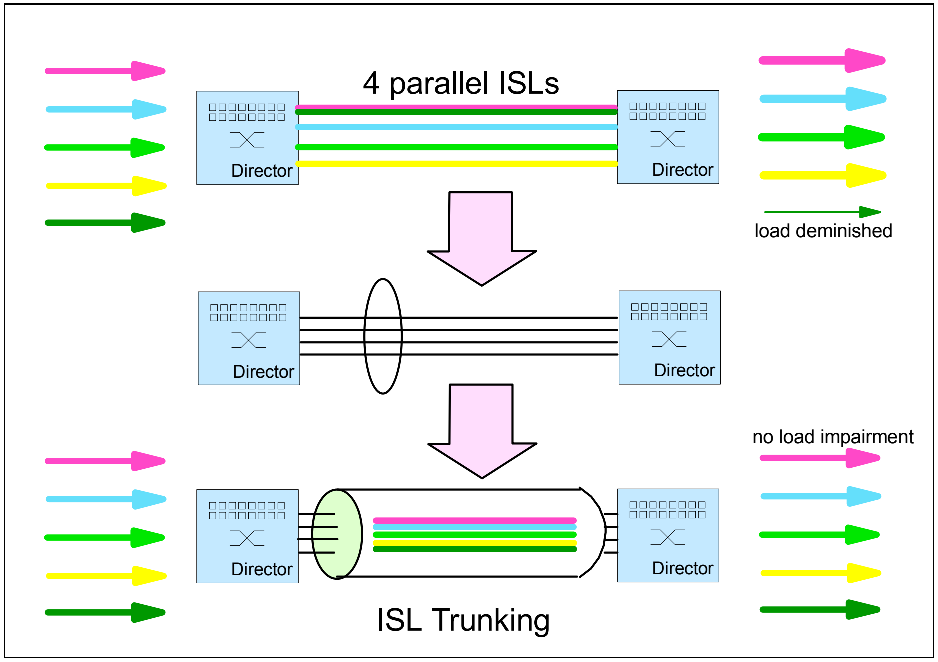


Figure 6-11 2109 ISL trunking

Because the full bandwidth of each physical link is available with ISL trunking, no bandwidth is wasted by inefficient load sharing. As a result, the entire fabric is utilized more efficiently. Moreover, Fabric OS and Management software like Fabric Watch views the group of physical ISLs as a single logical ISL. A failure of a single ISL in a trunk is only a reduction of the available bandwidth and not a failure of the complete route. Therefore, no re-calculation of the routes at that time is needed, and bandwidth automatically increases when the ISL is repaired.

ISL trunking will help simplify fabric design, lower provisioning time, it enhances switch-to-switch performance, simplifies management, and improves the reliability of SANs and in-order delivery is still guaranteed.

Load sharing and load balancing: Non-trunked, parallel ISLs always shared load or traffic in a rough, server-oriented way: The next server gets the next available ISL, regardless of the amount of traffic each server is generating. Load balancing, however, is the means to find an effective way to use all of the cumulative bandwidth of the parallel ISLs.

6.8.3 Switch count

The ultimate limitation in fabric design is a maximum of 239 physical switches, whatever switches are used. This limit is imposed by the actual number of domain IDs that can be uniquely established in the Fibre Channel Device ID header on the frames. The practical limit, as tested, allows for considerably fewer switches. Tests are conducted on SAN fabrics of up to 32 switches, with no more than seven hops supported from the source port to the destination port.

The hop count limit is set by the Fabric OS and is used to derive a frame hold time value per switch. The hold time value is the maximum amount of time a frame can be held in a switch before it is dropped (class 3) or F_BSY (class 2) is returned. A frame would be held if its destination port is not available. The hold time is derived from the error detect time-out value and the resource allocation time-out value using a formula as follows:

- **E_D_TOV:** Error detect time-out value. When this time is exceeded and the sending port has not been notified of receipt of data by the receiving port for a transmission, this error condition occurs (2 s default in IBM SAN Switches)
- **R_A_TOV:** Resource allocation time-out value. A fabric resource with a reported error condition that is not cleared will be locked out from reuse for this time. Minimum R_A_TOV computes to two times E_D_TOV (10 s default in IBM SAN Switches)
- **Holdtime:** The Holdtime = (R_A_TOV - E_D_TOV) / (Hop Count +1) / 2 ms (where time value is in milliseconds. For 7 hops, and the default E_D_TOV of 2000 milliseconds, the hold time per switch is 500 ms.

Note: The value of 7 for maximum hops is a Fabric OS parameter used to derive hold time. The actual hops in the fabric are not monitored and restricted to 7. More hops are possible; increasing R_A_TOV from the default will allow for longer switch hold times prior to an error condition. However, the default value for the hops has been chosen as a reasonable limitation in fabrics composed of up to 32 switches. This value has been chosen so there should be more than adequate time to allow for frame traffic to traverse the fabric, unless there is a problem preventing a port from responding.

6.8.4 Distributed fabrics

The data transmission range is up to 500 m for shortwave fiber link and up to 10 kilometers for longwave fiber link. There are also extra long distance GBICs on the market which can drive the optical signal distances of up to about 70 km.

To distribute fabrics over extended distances, IBM offers two new optional features, which we describe in the following sections.

Extended Fabric

This feature enables fabric interconnectivity over Fibre Channel at distances up to 120 km. In this implementation, ISLs use either, DWDM devices, extended LW-GBICs or dark fiber repeater-connections to transfer data. The Extended Fabric feature optimizes switch buffering to ensure the highest possible performance over ISLs. With the Extended Fabric feature the ISLs are configured with up to 60 buffer credits and optimizes buffers for up to 120 on 1 Gb/s fiber optic link, and up to 60 km on 2 Gb/s fiber optic link.

In a fabric consisting of 2109-Mxx and -Fxx switches, the long distance ISL that connects both locations, must be installed between edge port switches of the same model. An Extended Fabric does not work if the long distance ISL is installed between non-matching edge port switches, for example between an M12 and an F16.

The enhanced switch buffers help ensure that data transfer can occur at near-full bandwidth to efficiently utilize the connection over the extended links. To enable the Extended Fabric feature, the license must be installed on each switch in the fabric, the long distance Extended Fabric configuration has to be set only at the edge port connector switch. This switch automatically manages the rest of the switches in the extended fabric.

A high level view of an extended fabric is shown in Figure 6-12.

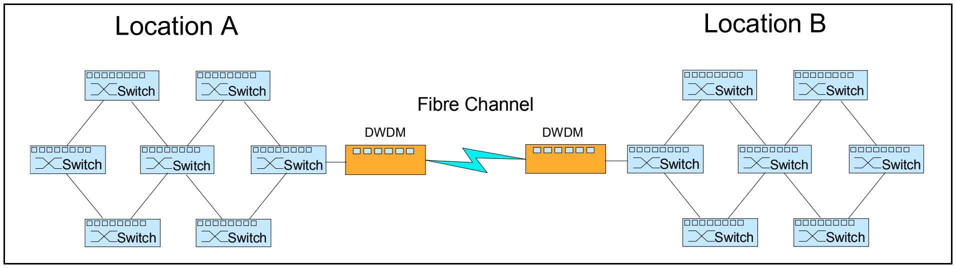


Figure 6-12 Extended Fabrics feature using dark fiber and DWDM

Remote Switch

This feature enables two switches to interconnect over a WAN by *gateways* (or network-bridges). The gateway supports both Fibre Channel Physical Interface as well as a secondary interface such as ATM. It accepts Fibre Channel frames from one side of a Remote Switch fabric, tunnels them across the network, and passes them to the other side of the Remote Switch fabric. This implementation is ideal for environments where dark fiber is not available or when the distance between the two sites exceeds 100 km. To enable the Remote Switch feature, the Remote Switch license must be installed on both switches connecting to the gateway, and the configuration has to be changed on this switch pair.

Both of these optional features are enabled through software capabilities in the switch. A SAN implemented via the Extended Fabric or Remote Switch feature provides all the facilities currently available in locally connected SANs such as these:

- **Single, distributed fabric services such as the name server and zoning:** Each device attached to the SAN appears as a local device, simplifying deployment and administration.
- **Comprehensive management environment:** All management traffic flows through internal SAN connections (IP over Fibre Channel) to allow the fabric to be managed from a single administrator console using Web Tools switch management software.

An example of a remote switch fabric is shown in Figure 6-13.

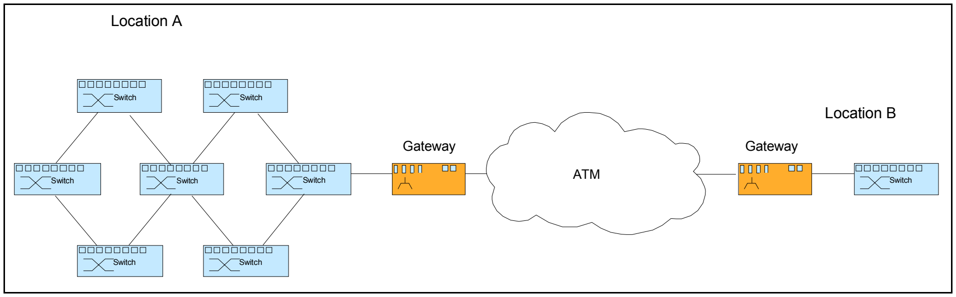


Figure 6-13 Remote Switch feature using ATM

6.9 Zoning

Zoning allows you to partition your SAN into logical groups of devices that can access each other. Using zoning, SAN administrators can automatically or dynamically arrange fabric-connected devices into logical groups (zones) across the physical configuration of the fabric. Although zone members can access only other members in their zones, individual devices can be members of more than one zone.

This approach enables the secure sharing of storage resources, a primary benefit of storage networks. The number of devices that can participate in a zone and the number of zones that can be created are virtually unlimited. SAN administrators can specify zones at a port-level, at server- or storage-level or at department-level. Likewise, zones can vary in size and shape, depending on the number of devices included and the location of the devices. Multiple zones can be included in saved configurations, providing easy control over the enabling or disabling of configurations and avoiding manual changes to specific zones.

Because zone members can access only other members of the same zone, a device not included in a zone is unavailable to members of that zone. Therefore, you can use zones as follows:

- **Administer security:** Use zones to provide controlled access to fabric segments and to establish barriers between operating environments. For example, isolate systems with different uses or protect systems in a heterogeneous environment.
- **Customize environments:** Use zones to create logical subsets of the fabric to accommodate closed user groups or to create functional areas within the fabric. For example, include selected devices within a zone for the exclusive use of zone members, or create separate test or maintenance areas within the fabric.

- **Optimize IT resources:** Use zones to consolidate equipment, logically, for IT efficiency, or to facilitate time-sensitive functions. For example, create a temporary zone to back up non-member devices.

Figure 6-14 shows four zones which allow traffic between two Fibre Channel devices each:

- iSeries server and ESS (Zone A)
- UNIX server and ESS (Zone B)
- zSeries server and ESS (Zone C)
- Windows server and ESS (Zone D)

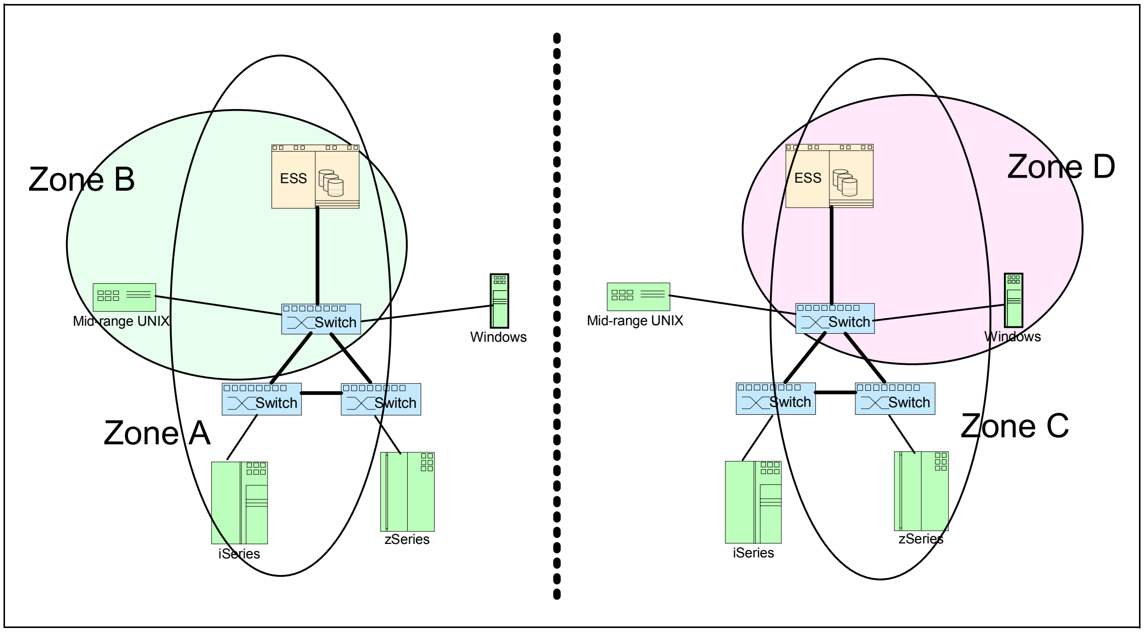


Figure 6-14 IBM SAN Switch zoning

Without zoning, failing devices that are no longer following the defined rules of fabric behavior might attempt to interact with other devices in the fabric. This type of event would be similar to an Ethernet device causing broadcast storms or collisions on the whole network instead of being restricted to one single segment or switch port. With zoning, these failing devices cannot affect devices outside of their zone.

6.9.1 Preparing to use zoning

Before you start using zoning, you should consider the naming conventions that you will be applying to zone related components. In the long run, adherence to a well documented and thought intensive naming convention will make life easier for all concerned.

Before implementing zoning, remember that the zoning process itself has the following advantages:

- Zoning can be administered from any switch in the fabric. Any changes configured to one switch automatically replicate to all switches in the fabric; if a new switch is added to an existing fabric, all zone characteristics are automatically applied to the new switch. Because each switch stores zoning information, zoning ensures a high level of reliability and redundancy.
- Zones can be configured dynamically. Configuring new zones does not interrupt traffic on unaffected ports or devices. Zones do not affect data traffic across inter-switch links (ISLs) in cascaded switch configurations.
- Zoning uses policy-based administration. Because zoning uses policy-based administration, separating zone specification from zone enforcement, you can manage multiple zone configurations and easily enable a specific configuration when it is required. A fabric can store any number of zone configurations; however, only one configuration is active at a time. But, because the configurations are pre-determined and stored, a new configuration can be easily enabled.
- Zoning can be configured and administered using the command line interface (CLI) or Web Tools.

6.9.2 Increasing availability

The easiest way to increase system availability is to prevent failures from ever occurring, typically by monitoring fabric activity and performing corrective actions prior to an actual failure. By leveraging advanced SAN features such as zoning and predictive management, companies can deploy a much more reliable and resilient SAN environment. To help prevent localized failures from impacting the entire fabric, specific parts of SANs can be isolated through the use of zoning, in which defined zones limit access between devices within the SAN fabric. SAN administrators can specify different availability criteria at the connection, node, and network level to address the potential impact of certain types of outages.

For instance, several minor outages in one environment might be much less destructive than a single large outage in another environment — even if the total amount of downtime is the same. The use of zoning helps limit the types of interactions between devices that might cause failures, and thus prevents outages. Especially as companies build larger SANs with heterogeneous operating systems and storage systems, zoning is an effective way to prevent failures.

6.9.3 Advanced zone terminology

A zone generally is a group of fabric-connected devices arranged into a specified group. Any device connected to a fabric can be included in one or more zones. Devices within a zone gain awareness of other devices within the same zone by the RSCN protocol (see 3.1.4, “RSCN” on page 93); they are not aware of devices outside of their zone. By these means, zoning provides data exchange between devices in the same zone and prohibits exchange to any device not in the same zone.

Advanced zoning of the 2 Gb/s switches compared with the *zoning* of 1 Gb/s switches enlarges the range of hardware enforcement and so provides the switch with more security access control functions as before, preventing unauthorized devices from accessing the fabric.

Attention: As zoning functions have developed, some items within the zone terminology have changed slightly with the availability of the 2 Gb/s switches.

Zone members

A zone member must be specified either by:

- Switch port (domain, port)
- World Wide Node Name (WWNN)
- World Wide Port Name (WWPN)
- Alias
- AL_PA in QuickLoop configurations

Zone members are grouped into a zone. To participate in a zone, the members must belong to the appropriate Access Control List (ACL) maintained in the switch hardware. Any number of ports in the fabric can be configured to the zone, so the number of members of a zone is unlimited.

Zones can overlap; a device can belong to more than one zone and a fabric most likely will consist of multiple zones. A zone configuration can include both hard and soft zones. There can be any number of zone configurations resident on a switch; however, only one configuration can be active at a time. Because the number of zones allowable is limited only by memory usage, the maximum number is virtually limitless.

Alias: Aliases exist to make life easier for administration. They are defined by [domain,port] or WWN and provide the opportunity to assign a nickname to a port or a device such as: `Server_Adrian_HBA0` instead of having to deal with a WWN such as `20:00:00:00:c9:2b:db:f0`.

The option to overlap zones is essential for secure storage resource sharing. The ability to share storage resources through logical volume allocation requires that multiple servers share a physical path into the storage. Overlapping zones enable each server (or groups of servers) to reside in a zone with the storage connection while another hardware zone can also see the storage connection. The two distinct zones and all their devices cannot communicate with each other, only with the shared storage system.

Figure 6-15 shows three servers separated by zone A,B and C, able to exchange data with the ESS.

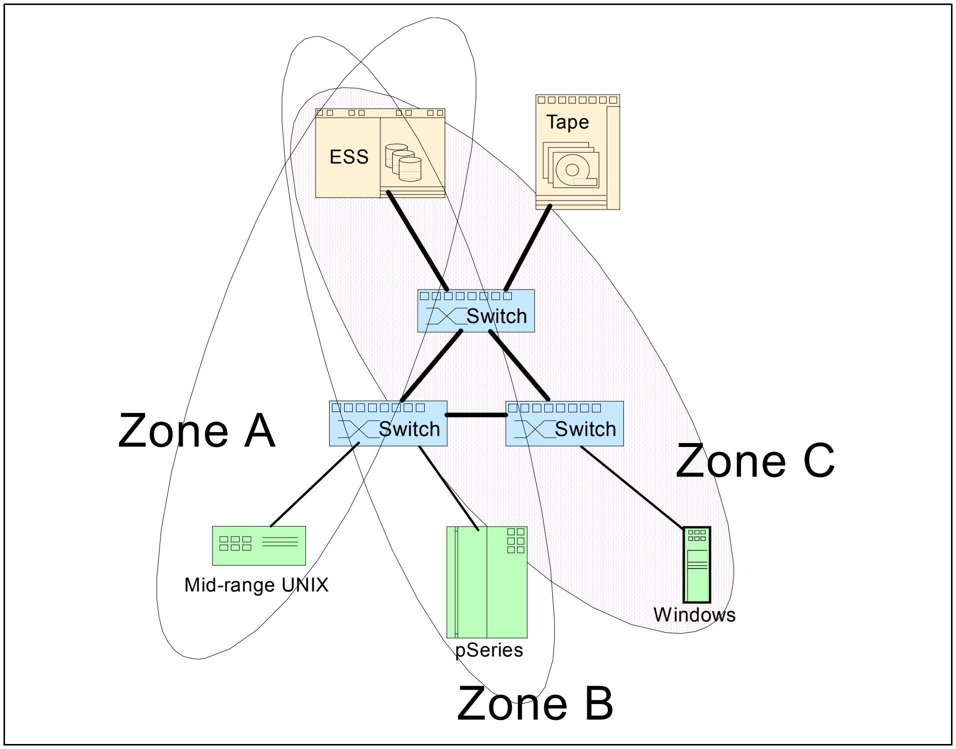


Figure 6-15 Overlapping zones

6.9.4 Zoning types

With advanced zoning, there are two different kinds of *enforcement* and four different kinds of *zoning*, as we explain in the following topics.

Hardware enforcement

This is achieved by the following types of zoning:

- **Hard port zoning:** In this case, all members are specified by [domain, port].
- **WWN zoning:** In this case, all members are specified by WW(P)N.

All zone members are specified exclusively either by [domain, port] or by WWN (that includes also WWPN). Hardware enforced zones mean that each frame is checked by hardware before it is delivered to a zone member, and discarded if there is a zone mismatch. Overlapping zones (zone members appearing in multiple zones) are permitted, and hardware enforcement will continue as long as all of the overlapping zones have either all WWNs or [domain,port] entries.

- **Broadcast zoning:** The broadcast zone is a special case; it controls the delivery of broadcast packets within a fabric. Used in conjunction with IP-capable HBAs, a broadcast zone restricts IP broadcast traffic to those elements included in that zone. Only one broadcast zone can exist within a fabric. Broadcast zones are independent of any other zones. A broadcast transfer will be delivered to all ports defined in the broadcast zone even though a port is protected by a hard zone.

Switch port in the M12: *Area* is considered the absolute port number and ranges from 0 through 63 for each logical switch and defines a specific port for zoning commands. For the ease of description, we still note switch ports [domain, port], although it should be noted as [domain, area] within the M12 with respect to Fabric OS v4.x. For more details on how the port numbering scheme within the M12 works, see “M12 port numbering scheme” on page 193.

Software enforcement

This type is also called *name server* enforcement:

- **Soft port zoning:** Here, all members are part of port **and** WWN zoning. Each port that is part of a port zone **and** a WWN zone is referred to as a “soft port”. That means that it will now follow name server enforcement rules; however, it is still complemented by *hardware-assisted authentication*. This means that any access of a FC device to the “soft port” is still checked by hardware and refused when the device is not in the same zone.

Hardware-assisted authentication: As fabric login exchanges continue to be enforced by the ASIC, any attempt by a misbehaving, unauthorized device (PLOGI / ADISC / PDISC / ACC) would get aborted before completion and no SCSI transaction could ever be performed, thereby guaranteeing data access control.

With the 1 Gb/s switches, a hardware zone had to be defined by [domain, port] only — all other configurations were soft zones. Now in mixed fabrics, consisting of both types of 1 Gb/s and 2 Gb/s switches, when there is at least one “soft port” in the configuration, each type of switch stays with its unique zoning method. In 1 Gb/s switches, they use soft zoning; in 2 Gb/s switches, they use soft zoning, hardware-assisted.

6.9.5 Zone configuration

Zones are grouped in a configuration. A zone configuration can carry both hardware and software enforced zones of virtually any amount. Switches can store any number of zone configurations in their memory; however, only one configuration can be active at a time. The number of zones allowable is limited only by memory usage.

In Table 6-1 we show a comparison of the different zone types that can be in a zone configuration.

Table 6-1 Different zone types

Feature	Hard zone	Soft zone	Broadcast zone
Naming Convention	Zone names must begin with a letter; may be composed of any number of letters, digits and the underscore character "_". Zone names are case sensitive. Spaces are not allowed within the name.		Special name "broadcast"
Name Server Requests	All devices in the same zones (hard or soft) as the requesting elements		NA
Hardware Enforced Data Transfers	Yes	Yes	Yes
Registered State Change Notification (RSCN)	State changes on any devices within the same zones.		NA
Eligible Devices	All members specified either by [domain, port] or WW(P)N	One member specified by [domain, port] and WW(P)N	Fabric Port Numbers or World Wide Names
Maximum Number of Zones	Limited by total available memory		1
Maximum Number of Zone Members	Limited by total available memory		
Fabric Wide Distribution	Yes	Yes	Yes
Aliases	Yes	Yes	Yes
Overlap	An element can be a member of an unlimited number of zones in any combination of hard and soft zones and be a member of the broadcast zone.		

Managing multiple zones

This is a policy-based administration which allows the user to manage multiple zone specifications and rapidly enable a specific configuration when required. This provides flexibility in rapidly making SAN configuration changes with minimal impact and risk.

Multiple zone configurations

A fabric can store multiple zone configurations with any one configuration being active at a time. This capability can be used in many ways. For example, a policy can be defined to provide access to the tape library to Windows hosts during the day for continuous backup, but migrate access to UNIX hosts at end of day.

Policy based management

As an example, imagine you have a storage subsystem that under normal circumstances is shared among multiple hosts. Your disaster policy provides that this storage subsystem can be used exclusively by a single host to recover critical data. Using policy-based zoning administration, both zoning configurations are configured and stored in the fabric. In the event of disaster, the SAN administrator would simply enable the pre-configured zoning configuration — a few mouse clicks — and the fabric would automatically enforce your pre-determined policy.

6.9.6 Zoning administration

Zoning administration can be managed either using the Command Line Interface to any switch in the fabric or by using Web Tools. Configuring zones consists of four steps:

- **Create aliases:** The aliases allow you to rapidly give familiar name or group multiple devices into a name. For example, you can create an alias called “NT_Hosts” to define all NT hosts in the fabric.
- **Define zones:** You can create a zone and add members to it. Members can consist of Switch Port Names, WWNs, or aliases. Changes to the zone layout does not take effect until a zone configuration has been defined and enabled.
- **Define a zone configuration:** You can create a zone configuration and add zones to it. This step identifies the zones that should be enabled whenever this configuration is enabled. Changes to the zone configuration will not take effect until that zone is enabled.
- **Enable the zone configuration:** Select the zone configuration to be activated. For hard zones, this action downloads the zone configuration to the switch ASICs and begins the enforcement. For either hard or soft zones, a State Change Notification (RSCN) is issued to signal hosts to re-query the name server for a list of available devices.

Zoning is a fabric-wide resource administered from any switch in the fabric and automatically distributes itself to every switch in the fabric, and simplifies administration. Zone definitions and zones configurations are persistent and remain in effect across reboots and power cycles until deleted or changed.

A new switch added to the fabric automatically inherits the zoning configuration information and immediately begins enforcement. The fabric provides maximum redundancy and reliability since each switch stores the zoning information locally and can distribute it to any switch added to the fabric.

6.9.7 QuickLoop

The QuickLoop feature combines arbitrated loop and fabric support for private loop *servers*. Private-loop storage *devices* like disk and tape can be connected to and used on each switch without the QuickLoop feature. Address translation for targets (storage devices) is basically implemented in each 2109 OS.

Looplets

A QuickLoop consists of multiple private arbitrated looplets (a set of devices connected to a single port) that are connected by a fabric. All devices in a QuickLoop share a single AL_PA space and behave as if they are in one loop. This allows private devices to communicate with other devices over the fabric, provided they are in the same QuickLoop.

QuickLoop topology has the following characteristics:

- A QuickLoop can include up to two switches and support up to 126 devices.
- Each individual switch can only be included in one QuickLoop.
- A QuickLoop can include either all or a subset of the ports on an individual switch.
- Multiple QuickLoops can exist in a fabric of multiple switches.
- QuickLoop enabled switches can exist in the same fabric as non-QuickLoop enabled switches.
- A device attached to a QuickLoop can communicate with all other devices attached to the same QuickLoop.
- A private device in a QuickLoop can communicate with devices in the same QuickLoop only. Existing PLDA capable host drivers need no modification to perform I/O operations with storage devices.
- Public devices that are arbitrated loop capable are treated as private devices when connected to QuickLoop ports (their fabric login, or “FLOGI,” is rejected).

- QuickLoop supports the use of legacy loop devices, allowing them to be attached to a fabric and operate as if in a Private Loop Direct Attach (PLDA) environment.
- QuickLoop functionality can be enabled or disabled for either the entire switch or for individual ports. When QuickLoop is disabled on an individual port, that port returns to fabric mode.
- Each looplet in a QuickLoop has its own unshared bandwidth and can support transfer rates up to 100 MB/s.
- Multiple devices can communicate simultaneously and at full bandwidth within multiple looplets located in the same QuickLoop.
- If a looplet error is detected, QuickLoop automatically takes the looplet out of service. If the error condition is cleared, the looplet is automatically reinstated.

Private loop migration

QuickLoop provides a potential migration path from deploying a single private loop to deploying a fabric-based SAN. Initially, QuickLoop enabled switches can be used to replace hubs when the SAN is first deployed and only has private devices attached. Then, as the SAN grows, fabric switches can be added without any detrimental effect to the QuickLoop enabled switches.

Address translation

QuickLoop address translation is transparent and requires no actions on the part of the user. It is achieved through hardware translative mode (also known as phantom mode), in which a device not physically located in a looplet is made addressable by a unique AL_PA in that looplet. There are two hardware translative modes available to a QuickLoop enabled switch:

- **Standard translative mode:** Allows public hosts to communicate with private target devices across the fabric.
- **QuickLoop mode:** Allows private hosts to communicate with private target devices across the fabric.

The switch automatically determines and sets the appropriate mode.

QuickLoop and zoning

QuickLoop can be used in conjunction with zoning. Using the products together provides the following additional features:

- AL_PAs from multiple QuickLoops can be used to add members to a zone. This is due to the Zoning ability to name QuickLoops and therefore identify the QuickLoop to which the AL_PA belongs.

- Additional control over access to QuickLoop devices is possible. Fabric devices in a zoned fabric can only access the QuickLoop (and fabric) devices that are in the same zone.
- Zones can be created within QuickLoops. Zoning can be used to partition QuickLoops. This creates "QuickLoop zones" (as opposed to fabric zones), which support identification by either physical port number or AL_PA.

6.10 Fabric management

The switch can be managed using several remote and local access methods. Telnet, SNMP, and Web Tools require an IP network connection to the switch; either out-of-band via switch Ethernet port, or in-band via the Fibre Channel. The switch must be configured with an IP address fitting into the environment's IP addressing scheme.

In Table 6-2 we show a comparison of the access methods.

Table 6-2 Comparison of management access method

Management method	Description	Local	In-band (Fibre Channel)	Out-band (Ethernet)
Serial Port	CLI locally from serial port on the switch	Yes	No	No
Telnet	CLI remotely via Telnet	No	Yes	Yes
SNMP	Manage remotely using the simple network management protocol (SNMP)	No	Yes	Yes
Management Server	Manage with the management server.	No	Yes	No
SES	Manage through SCSI-3 enclosure services	No	Yes	No
Web Tools	Manage remotely through graphical user interface	No	Yes	Yes

6.10.1 Web Tools

Web Tools (also called the IBM TotalStorage StorWatch Switch Specialist) is an intuitive graphical user interface (GUI) which allows network managers to monitor and manage SAN fabrics consisting of switches using a Java-capable Web browser from standard desktop workstations. By entering the network address of any switch in the fabric, the built-in Web server automatically provides a full view of the switch fabric. From that switch, the administrator can monitor the status and perform administration and configuration actions on any switch in the SAN.

Web Tools can manage the switches in the fabric either using in-band Fibre Channel connections or out-of-band Ethernet connections.

To increase SAN management security, Web Tools can operate over a secure browser using the Secure Sockets Layer (SSL) protocol. This protocol provides data encryption, server authentication, message integrity, and optional client authentication for TCP/IP connections. Because SSL is built into all major browsers and Web servers, installing a digital certificate activates the SSL capabilities.

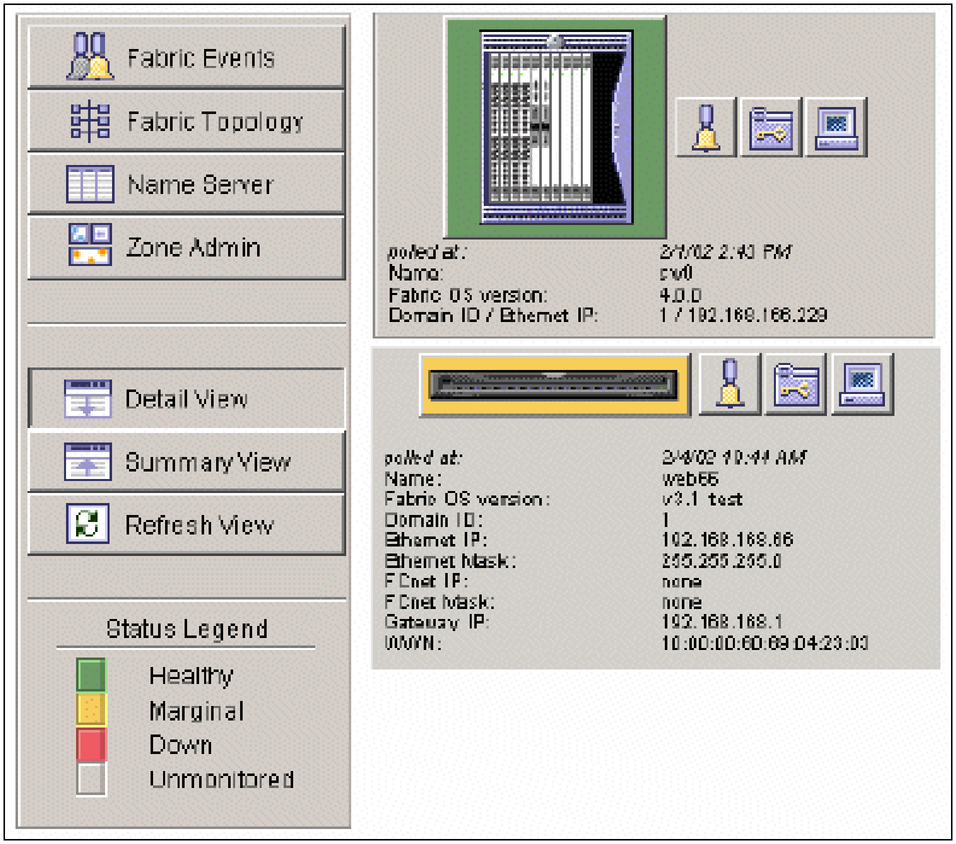
Central status monitoring

Web Tools enables management of any switch in the fabric from a single access point. Using a Web browser, Web Tools is quickly accessed by simply entering the name or IP address of any switch. The Web Tools menu then appears in the Web browser’s window, where information about all switches can be retrieved.

The Web Tools menu includes the following views:

- **SAN Fabric View:** Displays all switches in the fabric on a single screen. This graphical display shows all switches currently configured in the fabric and provides a launch point for monitoring and administrating any switch in the SAN. It scales well to large fabrics via a Summary View, which can show twice as many switches as the default detail view.
- **Fabric Event View:** Displays events collected across the entire fabric from the built-in messaging system on each switch, or more detailed and managed information provided by Fabric Watch, an optional feature. Fabric events may be sorted by key fields such as date-time, switch source, or severity level.
- **Fabric Topology View:** Summarizes the physical configuration of the fabric from the perspective of the *local domain* (the domain of the switch entered as a URL in the Web browser).
- **Name Server View:** Displays information about all hosts and storage devices that are currently registered in the fabric. The Name Server Table is automatically updated when new hosts or devices join the fabric.

- **Zone Admin View:** Administrative privileges are required to access this view. The SAN administrator will manage the switch configuration by menu selection, including a check for possible zoning conflicts before applying the changes to the switch.
- **Detail & Summary View:** Select this to view either the Summary or Detail version of the Fabric View. The Summary version shows abbreviated switch panels. The default view is Detail.
- **Refresh View:** Select this to update the Fabric View to display the latest changes. The Refresh button icon will flash when there have been changes. The Refresh button is only available on switches running Fabric OS 4.x. and higher.



🟩	Healthy
🟨	Marginal
🟥	Down
⬜	Unmonitored

polled at:	2/1/02 2:43 PM
Name:	sw0
Fabric OS version:	4.0.0
Domain ID / Ethernet IP:	1 / 192.168.166.229

polled at:	2/4/02 10:44 AM
Name:	web66
Fabric OS version:	v3.1 test
Domain ID:	1
Ethernet IP:	192.168.168.66
Ethernet Mask:	255.255.255.0
FCnet IP:	none
FCnet Mask:	none
Gateway IP:	192.168.168.1
WWN:	10:00:00:60:69:04:23:03

Figure 6-16 Web Tools detailed view

Switch access

From the fabric view, SAN administrators click on any switch icon to establish communication with individual switches for in-depth monitoring or to access configuration options. Individual switch views include:

- The Switch View is an active point-and-click map of the selected switch. Each port icon displays current port status. A click on a port takes the user to the Port Detail View. The states of power supply, fan, and temperature health are updated dynamically. Tool Icons in the Switch View permit direct access to the Event View, the Administrative View, the Performance View, the Fabric Watch Configuration Page (if licensed), the Administrative View, and the Switch Beaconing function.
- The Event View provides a sortable view of all events reported by the switch.
- The Performance View graphically portrays real-time through-put information for each port and the switch as a whole.
- The Telnet icon provides an interface to Telnet functions to perform special switch functions and diagnostics via a Command Line Interface.

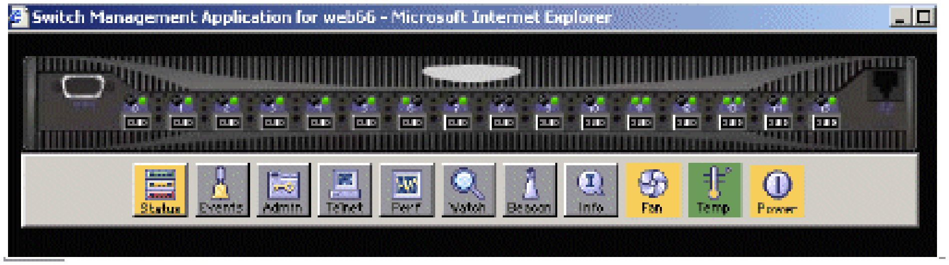

Switch Management Application for web66 - Microsoft Internet Explorer
Status
Events
Admin
Telnet
Perf
Watch
Beacon
Info
Fan
Temp
Power

Figure 6-17 Web Tools switch view

Central zoning administrative control

For multi-switch fabric configurations that include the zoning feature, Web Tools enables users to update zoning functions through a graphical user interface.

Fabric OS instantly distributes zoning configuration changes to all switches in the fabric. In addition, users of QuickLoop may use WebTools to configure QuickLoop and integrate QuickLoop with zoning.

Administration and configuration

With Web Tools, SAN administrators can configure and administer individual ports or switches. Web Tools provides an extensive set of features, which enable SAN administrators to quickly and easily perform the major administrative functions of the switch, such as these:

- Configuring individual switches’ IP addresses, switch name, and SNMP settings
- Rebooting a switch from a remote location
- Upgrading switch firmware and controlling switch boot options
- Maintaining administrative user logins and passwords
- Controlling individual ports
- Managing license keys
- Updating multiple switches with similar configurations

6.10.2 Advanced Performance Monitoring

Advanced Performance Monitoring is essential for optimizing fabric performance, maximizing resource utilization, and measuring end-to-end service levels in large SANs. It helps to reduce total cost of ownership (TCO) and over-provisioning while enabling SAN performance tuning and reporting of service level agreements. Advanced Performance Monitoring enables SAN administrators to monitor transmit and receive traffic from the source device all the way to the destination device. Single applications such as Web serving, databases, or e-mail can be analyzed as complete systems with near-real-time performance information about the data traffic going between the server and the storage devices. This end-to-end visibility into the fabric enables SAN administrators to identify bottlenecks and optimize fabric configuration resources.

Advanced Performance Monitoring supports loop, and switched fabric topologies.

Here are some examples of what can be monitored using Telnet:

- **AL_PA monitoring:** Provides information regarding the number of CRC errors in Fibre Channel frames in a loop configuration. It collects CRC error counts for each AL_PA attached to a specific port.
- **End-to-End monitoring:** Provides information regarding performance between a source and a destination on a fabric or a loop. Up to eight device pairs can be specified per port. For each of the pairs, the following information is available:
  - CRC error count on the frames for that device pair
  - Fibre Channel words that have been transmitted through the port for them
  - Fibre Channel words that have been received by the port for them
- **Filter-based monitoring:** Provides information about a filter’s hit count. All user-defined filters are matched for all FC frames being transmitted from a port. A filter consists of an offset (byte offset into the FC frame that is) and up to four values. A filter will match, if all the values specified are found in the FC frame at the specified offset.

You can also administer and monitor performance using Web Tools, if a Web Tools license is also installed. The enhanced Advanced Performance Monitoring features in Web Tools provide:

- Pre-defined reports for AL_PA, end-to-end, and filter-based performance monitoring
- User-definable reports
- Performance canvas for application level or fabric level views
- Configuration editor (save, copy, edit, and remove multiple configurations)
- Persistent graphs across reboots (saves parameter data across reboots)
- Print capabilities

Advanced Performance Monitoring makes powerful underlying capabilities simple and easy to use. An enhanced graphical user interface launched from Web Tools gives administrators *at-a-glance* information needed to anticipate and resolve problems. Administrators can display up to eight performance graphs on a single user-defined management *canvas* (see Figure 6-19 on page 232).

Different canvasses can address different users, scenarios, or host applications. Saved canvas configurations enable administrators to change views quickly and easily. Because there is no need to identify a single management console, administrators can access and run the tool from any switch using the Web Tools browser at any location. Moreover, setting up end-to-end monitoring is straightforward, even for large SAN configurations. To further improve productivity, administrators can use powerful sort, search, and selection features to identify source-to-destination device pairs, dragging and dropping them from the topology tree.

A rich set of predefined graphs are provided for the most common tasks. In addition, administrators can customize predefined performance graphs on virtually any parameter, and add them to canvas configurations. They can also set up and generate printouts or reports in minutes by using previously saved or customized layouts, along with drag-and-drop screens.

Advanced Performance Monitoring can be implemented and used on any IBM 2 Gb/s switch. The performance monitoring features can be used as long as the data path of the target flows through a switch that has Frame Filtering capabilities. Existing switches do not need to be replaced or modified.

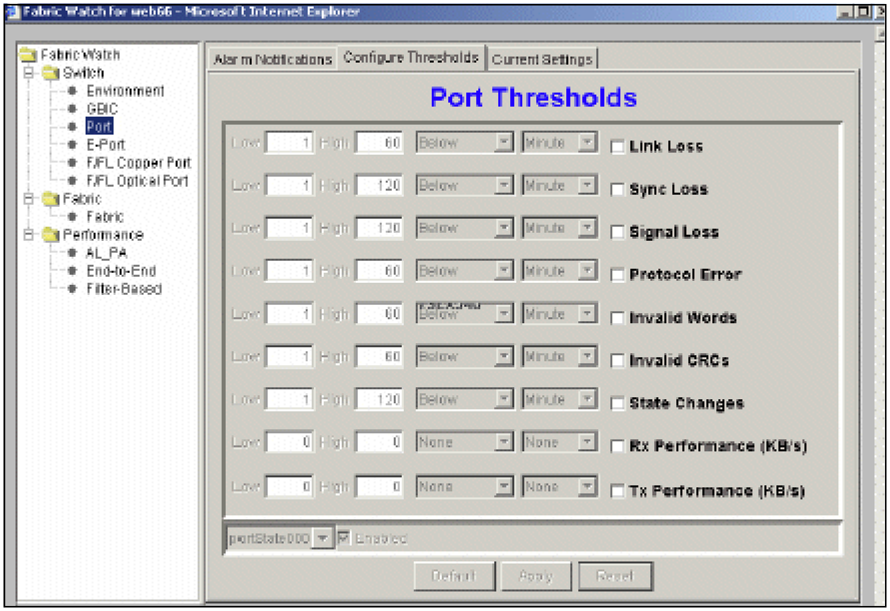
6.10.3 Fabric Watch

Fabric Watch health enables switches to continuously monitor the health of the fabrics, watching for potential faults based on defined thresholds for fabric elements and events, so making it easy to quickly identify and escalate potential problems. It monitors each element for out-of-boundary values or counters and provides notification to SAN administrators when any exceed the defined boundaries. SAN administrators can configure which elements, such as error, status, and performance counters within a switch, are monitored.

Accessing Fabric Watch

Fabric Watch runs on Fabric OS since version 2.2, and can be accessed through either Web Tools, Telnet interface, SNMP-based enterprise manager, or by modifying and uploading the Fabric Watch configuration file to the switch. It is designed for rapid deployment: simply enabling Fabric Watch (it comes with pre-configured profiles) permits immediate fabric monitoring. It is also designed for rapid custom configuration.

An example of Fabric Watch to monitor port thresholds is shown in Figure 6-18.



Port Thresholds

Low 1	High 60	Below	Minute	□ Link Loss
Low 1	High 120	Below	Minute	□ Sync Loss
Low 1	High 120	Below	Minute	□ Signal Loss
Low 1	High 60	Below	Minute	□ Protocol Error
Low 1	High 60	Below	Minute	□ Invalid Words
Low 1	High 60	Below	Minute	□ Invalid CRCs
Low 1	High 120	Below	Minute	□ State Changes
Low 0	High 0	None	None	□ Rx Performance (KB/s)
Low 0	High 0	None	None	□ Tx Performance (KB/s)

portState000 ☑ Enabled

Figure 6-18 Fabric Watch port thresholds monitor

SAN administrators can easily create and modify configuration files using a text editor, and then distribute configurations to all the switches in the SAN.

Range monitoring

With Fabric Watch, each switch continuously monitors error and performance counters against a set of defined ranges. This and other information specific to each monitored element is made available by Fabric Watch for viewing and, in some cases, modification.

Terminology: The set of information about each element is called a *threshold*, and the upper and lower limits of the defined ranges are called *boundaries*.

Fabric Watch monitors the following elements:

- Fabric events:
  - Topology reconfigurations
  - Zone changes)
- Switch environment:
  - Fans
  - Power supplies
  - Temperature)
- Ports:
  - State changes
  - Errors
  - Performance
  - Status of *smart* GBICs (Finisar SMART GBICs FTR-8519-3)

Figure 6-19 shows an example of the performance monitor.

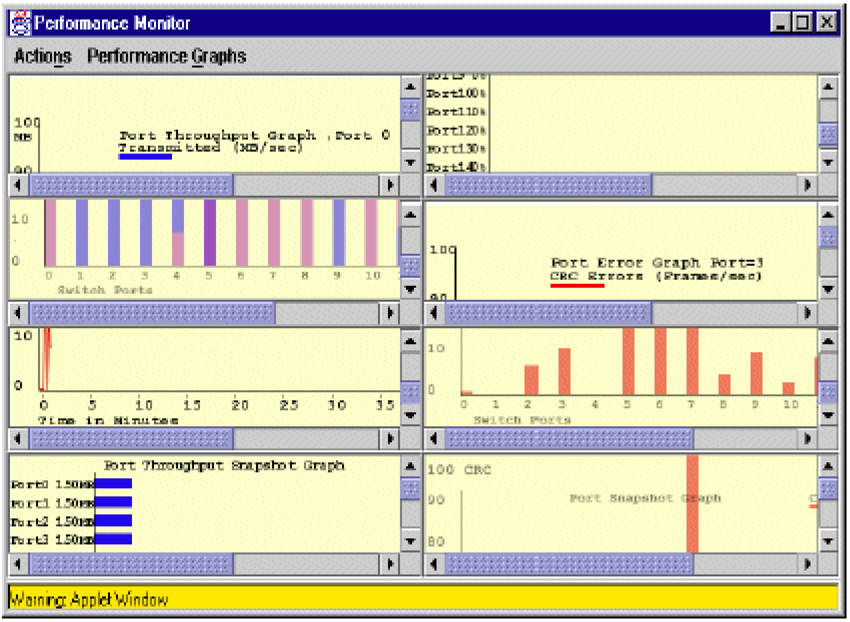


Figure 6-19 Fabric Watch Performance Monitor

Fabric Watch lets SAN administrators define how often to measure each switch and fabric element and specify notification thresholds. Whenever fabric elements exceed these thresholds it is considered as an event. Fabric Watch automatically provides an event notification, they come in two flavours:

- **Continuous Alarm:** Provides a warning message whenever a threshold is breached, and it continues to send alerts until the condition is corrected. For example, if a switch exceeds its temperature threshold, Fabric Watch activates an alarm at every measurement interval until the temperature returns to an acceptable level.
- **Triggered Alarm:** Generates *one* warning when a threshold condition is reached and a *second* alarm when the threshold condition is cleared. Triggered alarms are frequently used for performance thresholds. For example, a single notice might indicate that port utilization exceeds 80 percent. Another notice would appear when port utilization drops 80 percent.

These alarms (one or more) generated for the relevant threshold can have three consequences:

- **SNMP trap:** Following an event, Fabric Watch can transmit critical event data as an SNMP trap. Support for SNMP makes Fabric Watch readily compatible with both network and enterprise management solutions.
- **Entry in the switch event log:** Following an event, Fabric Watch can add an entry to an individual switch's internal event log, which stores up to 256 error messages.
- **Locking of the port log to preserve the relevant information:** Following an event, Fabric Watch can add an entry to an individual switch's internal port log and freeze the log to ensure detailed information is available.

Integration with existing management tools

SAN administrators can easily integrate Fabric Watch with existing enterprise systems management tools. Fabric Watch is designed for seamless interoperability with:

- **SNMP-based Enterprise Managers:** The Fabric Watch Management Information Base (MIB) lets system administrators configure fabric elements, receive SNMP traps generated by fabric events, and obtain the status of fabric elements through SNMP-based Enterprise Managers.
- **Web Tools:** By running Fabric Watch with Web Tools, SAN administrators can configure Fabric Watch and query fabric events from this graphical user interface.
- **Syslog daemon:** Through its integration with the UNIX operating system's standard interface for system logging and events, Fabric Watch will send SAN events into a central network log device.

6.10.4 Fabric Manager

Fabric Manager is a highly scalable, Java-based application that manages multiple switches and fabrics in real time. In particular, Fabric Manager provides the essential functions for efficiently configuring, monitoring, dynamically provisioning, and managing fabrics on a daily basis.

Through its single-point SAN management platform, Fabric Manager enables the global integration and execution of processes across multiple fabrics. Moreover, Fabric Manager helps to lower the cost of SAN ownership by intuitively facilitating a variety of SAN management tasks. As a result, Fabric Manager provides a flexible and powerful tool optimized to provide organizations with rapid access to critical SAN information across multiple fabrics.

Fabric Manager increases the efficiency levels of SAN administrators who are responsible for managing multiple SANs. With the unique ability to provide real-time information and streamline SAN management tasks, Fabric Manager provides the following capabilities:

- **A single-console global SAN management platform**: Fabric Manager has the intelligence to manage multiple switch elements spanning up to eight fabrics. It dynamically collects (in real time) all SAN fabric elements and portrays them within the single console, allowing intuitive iconic and explorer tree operations
- **Enhanced SAN visibility:** Fabric Manager can globally capture and present reliable status for all SAN objects. Status is projected through-out the entire SAN management environment. This context-sensitive feature enables SAN administrators to dynamically discover and control the status of all components.
- **An intuitive and functional object management platform:** Fabric Manager's visual display works efficiently with multiple SANs, Fabric Manager is a powerful, secure, and highly scalable management platform for configuring and administrating multiple SANs medium to large, and up to 200 switches. Fabric Manager provides the object status of critical fabric elements, such as ISL Trunking and fabric events, capturing this information in real time across multiple fabrics and fabric security levels.

Fabric Manager provides unique and intuitive methods for managing SANs, including these:

- **User-controlled SAN object grouping:** Fabric Manager enables fabric switches to be placed into any logical, user-defined groups, which are then dynamically propagated throughout Fabric Manager. The groups can be utilized at any time to simplify global management tasks, reducing execution time and ultimately lowering SAN management costs.

- **Global password control:** Fabric Manager enables the management of a user-definable set of SAN fabric switch passwords. SAN administrators can utilize these secure and encrypted objects across all secure features within the platform and across logical groups.
- **Advanced license key management:** Fabric Manager can manage license keys across all SAN fabrics under its control. License management is fully integrated with security, group, and password control.
- **Profiling, backup, and cloning:** Fabric Manager enables organizations to capture a profile of a switch within any fabric, back-up the snapshot to a safe place, and compare the backup to the original fabric device. Cloning facilitates the distribution of profiles to switches within the fabric.
- **Highly flexible firmware download:** This feature is dynamically configurable and scalable across logical groups, password controls, multiple fabrics, and SAN infrastructures with multiple security levels. When utilized with sequenced reboot, Fabric Manager provides a fully configurable environment for controlling the Fabric OS download process
- **Tight integration:** Fabric Manager is tightly integrated with all components of the IBM SAN management family and can in some cases extend those products' capabilities (such as Web Tools and Fabric Watch). As a result, Fabric Manager reduces the time and costs of managing SANs.

In-band and out-of-band: Web Tools uses in-band discovery mechanisms (through the SAN network itself) to discover devices. The in-band discovery mechanisms use SCSI inquiry commands. Many simple disk drives are discovered using in-band discovery. Another type involves out-of-band discovery mechanisms using Simple Network Management Protocol (SNMP) capabilities through TCP/IP and then correlating the results. Hosts and storage subsystems usually have out-of-band management capabilities. The out-of-band discovery gathers device and topology information.

Note: Switches can be accessed simultaneously from different connections. If this happens, changes from one connection may not be updated to the other, and some may be lost. Make sure, when connecting with simultaneous multiple connections, that you do not overwrite the work of another connection.

6.10.5 SCSI Enclosure Services

SCSI Enclosure Services (SES) allows an SES-enabled host connected to a fabric switch to manage all switches in the SAN. This is done remotely in-band using a Fibre Channel link. Therefore, SES serves as the access management method of choice for SCSI-based legacy environments where no Fibre Channel IP driver is available. The SES implementation complies with the SCSI-3 protocol standards used for implementing SES.

- Any SCSI-enabled host connected to the fabric can manage any switch.
- There is no single point of failure in the network.
- The SES capability automatically scales without needing additional resources as the fabric enlarges.

Managing a SAN using SES

To manage a SAN using SES, a host must have a Fibre Channel link to a switch in the fabric. The host must support FCP (Fibre Channel Protocol for SCSI-3) and recognize the FCP target at the Management Server well-known address (FFFFFAh). The host needs to perform the normal N_Port login procedure with the Management Server. It may then initiate an appropriate SES request.

Switch identification in SES

A switch is identified at the FCP level by its Logical Unit Number (LUN). To get a list of LUNs (switches) in the network, the FCP host sends a command to LUN 0 of the target at the Management Server well-known address. Thereafter, the host specifies a particular LUN during a management SES request.

Based on the management information obtained from SES, the SES host may perform a configuration, performance, and/or enclosure function on a switch. For instance, it may enable or disable a switch port, take the temperature sensor readings of a switch, or monitor the performance or error counters of a switch port.

SES helps to maintain a highly available environment for databases and business-critical information in distributed storage environments that are exclusively SCSI-based.

SES switch management

SES is an in-band mechanism for managing a switch within a fabric or other enclosures. SES commands are used to manage and sense the operational status of the power supplies, cooling devices, displays, indicators, individual drives, and other non-SCSI elements installed in a switch (enclosure). The command set uses the SCSI `SEND DIAGNOSTIC` and `RECEIVE DIAGNOSTIC RESULTS` commands to obtain and set configuration information for the switch.

Initiator communication

SES allows a SCSI entity (or initiator) to communicate with a switch through a standard FCP connection into the fabric. SES does not require supporting another protocol or additional network links such as Ethernet.

Figure 6-20 shows the fabric SES view.

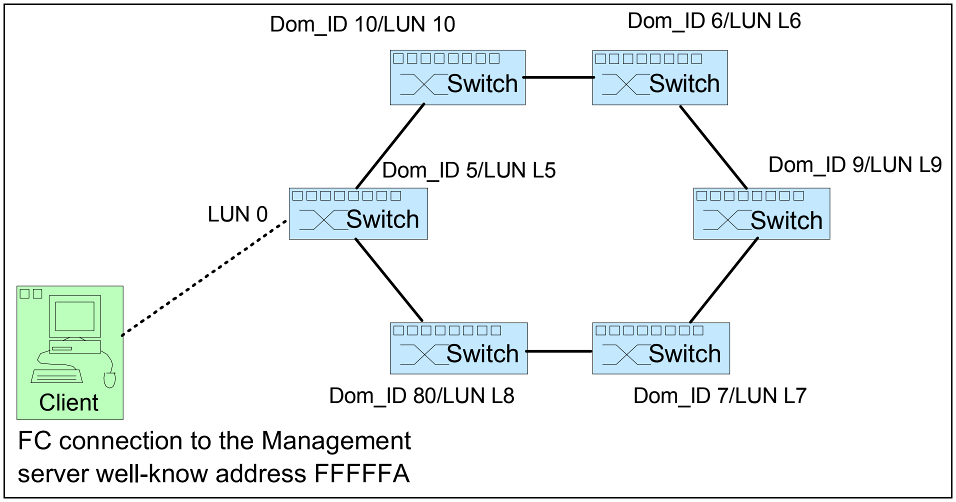


Figure 6-20 SES management

The switch's domain_ID is used as the LUN address to identify each switch including the switch used for access using SES.

Note that the connection to the fabric is through the switch labeled LUN L5 and which is also called LUN 0. The connection to the well-known management address (x'FFFFFA') is always labeled LUN 0 (value in hexadecimal is 00000000 00000000) no matter which switch is used.

Additionally, there can also be a LUN L0 with a hex value of 01000000 00000000. The figure also shows that the left most switch is assigned both LUN L5 and LUN 0. LUN L5 because the switch's domain_ID is L5, and LUN 0 because the client is physically connected to the switch.

6.11 Switch interoperability

The 2109-M12 and Fxx switches are OEM products from Brocade and identical to Brocade's SilkWorm switches:

- IBM SAN Switch 3534-F08 — Brocade SilkWorm 3200
- IBM SAN Switch 2109-F16 — Brocade SilkWorm 3800
- IBM SAN Switch 2109-F32 — Brocade SilkWorm 3900
- IBM SAN Switch 2109-M12 — Brocade SilkWorm 12000

The IBM 2109 SAN portfolio switches will therefore fully interoperate with Brocade SilkWorm products.

6.11.1 Interoperability matrix

This section lists the storage systems and servers supported for the IBM TotalStorage SAN Fibre Channel Switches. In order to refer to the latest compatibility information, we advise you to refer to the Web site:

`http://www.storage.ibm.com/ibmsan/products/2109/library.html#support`

The support matrix based on these models:

- IBM TotalStorage SAN Fibre Channel Switch Model 3534-F08 is shown in Table 6-3.
- IBM TotalStorage SAN Fibre Channel Switch Model 2109-F16 and 2109-F32 is shown in Table 6-4.
- IBM TotalStorage SAN Fibre Channel Switch Model 2109-M12 is shown in Table 6-5.

Table 6-3 3534-F08 - Fibre Channel support

IBM SAN Switch Model 3534-F08 - Fibre Channel support		
Storage systems	**Description**	**Platform/operating systems**
Disk Systems	ESS (IBM 2105-800, Fx0) FAStT700 (IBM 1742) FAStT500 (IBM 3552) FAStT200 (IBM 3542)	IBM pSeries (AIX 4.3.3 or later) IBM iSeries (running OS/400® V5R1 or later) IBM xSeries (running Linux, Netware and Windows NT/2000) IBM TotalStorage NAS 300G Intel-based servers (running Linux, Netware and Windows NT/2000) SUN servers (running Solaris 2.6,7,8) HP (running HP-UX 11.0 & 11i and Tru64 UNIX 4.0F or later)
Tape Systems	Enterprise Tape System (IBM 3590 & 3494) Ultrascalable Tape Library (IBM 3584) Scalable Tape Library (IBM 3583)	IBM pSeries (AIX 4.3.3 or 5.1) IBM iSeries (running OS/400 V5R1 or later) IBM xSeries (running Linux and Windows NT/2000) Intel-based servers (running Linux and Windows NT/2000) SUN servers (running Solaris 2.6, 7, 8) HP (running HP-UX 11.0 & 11i)

Table 6-4 2109-F16 & 2109-F32 Fibre Channel support

IBM SAN Switch Model 2109-F16 & 2109-F32- Fibre Channel support		
Storage systems	**Description**	**Platforms**
Disk Systems	ESS (IBM 2105-800, Fx0, Ex0) FAStT700 (IBM 1742) FAStT500 (IBM 3552) FAStT200 (IBM 3542)	IBM pSeries (AIX 4.3.3 or later) IBM iSeries (running OS/400 V5R1 or later) IBM xSeries (running Linux, Netware and Windows NT/2000) IBM TotalStorage NAS 300G Intel-based servers (running Linux, Netware and Windows NT/2000) SUN servers (running Solaris 2.6,7,8) HP (running HP-UX 11.0 & 11i and Tru64 UNIX 4.0F or later)
Tape Systems	Enterprise Tape System (IBM 3590 & 3494) Ultrascalable Tape Library (IBM 3584) Scalable Tape Library (IBM 3583)	IBM pSeries (AIX 4.3.3 or 5.1) IBM xSeries (running Linux and Windows NT/2000) Intel-based servers (running Linux and Windows NT/2000) SUN servers (running Solaris 2.6, 7, 8) HP (running HP-UX 11.0 & 11i)

Table 6-5 2109-M12 - Fibre Channel support

IBM SAN Switch Model 2109-M12 - Fibre Channel support		
Storage systems	**Description**	**Platform/operating systems**
Disk Systems	ESS (IBM 2105-800, Fx0) FAStT700 (IBM 1742) FAStT500 (IBM 3552) FAStT200 (IBM 3542)	IBM pSeries (AIX 4.3.3 or later) IBM xSeries (running Linux, Netware and Windows NT/2000) IBM TotalStorage NAS 300G Intel-based servers (running Linux, Netware and Windows NT/2000) SUN servers (running Solaris 2.6,7,8) HP (running HP-UX 11.0 & 11i)
Tape Systems	Enterprise Tape System (IBM 3590 & 3494) Ultrascalable Tape Library (IBM 3584) Scalable Tape Library (IBM 3583)	IBM pSeries (AIX 4.3.3 or 5.1) IBM xSeries (running Linux and Windows NT/2000) Intel-based servers (running Linux and Windows NT/2000) SUN servers (running Solaris 2.6, 7, 8) HP (running HP-UX 11.0 & 11i)

7

General SAN troubleshooting tips

In this chapter, we discuss general methods to determine the root cause of faults in a SAN. Networks are usually described as *complex* — which is true — but they are not necessarily *complicated*. However, complexity means that there is the presence of a structure. We have to utilize this structure, and understand it, in order to troubleshoot the network.

This chapter is not meant to replace the numerous maintenance and service manuals which come with the SAN products. Our aim is to help identify the type of data to look at if trouble occurs. You can navigate to the various product manuals from this Web site:

`http://www.storage.ibm.com/ibmsan/index.html`

7.1 Overview

SANs embrace servers, fabric, and storage devices, although SAN administration sometimes does not cover the whole range of related products and services. Depending on the size and structure of a company's IT operation, SAN administration may be responsible for switches and storage only. Servers may be administrated by a different group, and are often managed by a group focusing on applications. Such an administrative structure can introduce delays while searching for problem root causes.

For example, a SAN problem may appear as an application problem and will be treated as such until the application is ruled out as the cause. It is likely that at that stage it will be handed over to the SAN group responsible.

7.2 Reporting failure

The SAN administration group may receive information from an end user as basic as: "I cannot access my storage" — for a variety of possible failures. As the underlying Fibre Channel is transparent to the end user, most times a problem in the SAN will manifest itself as a SCSI storage failure to that end user.

Depending on the type and the reporting of such a fault — it may be an automated event notification from the management station, or a user's complaint — the SAN administrator should start and check event and alarm logs in server, switches, and storage devices for failure entries.

Switches provide the internal visibility medium to the fabric, as well as to both the server and storage side. Compared to the average amount and type of information you may receive from a server that cannot access its storage, you may find the information collected in the switch to be superior to that reported on the server.

In Figure 7-1 we show an example of a fabric that we will use to give some troubleshooting tips.

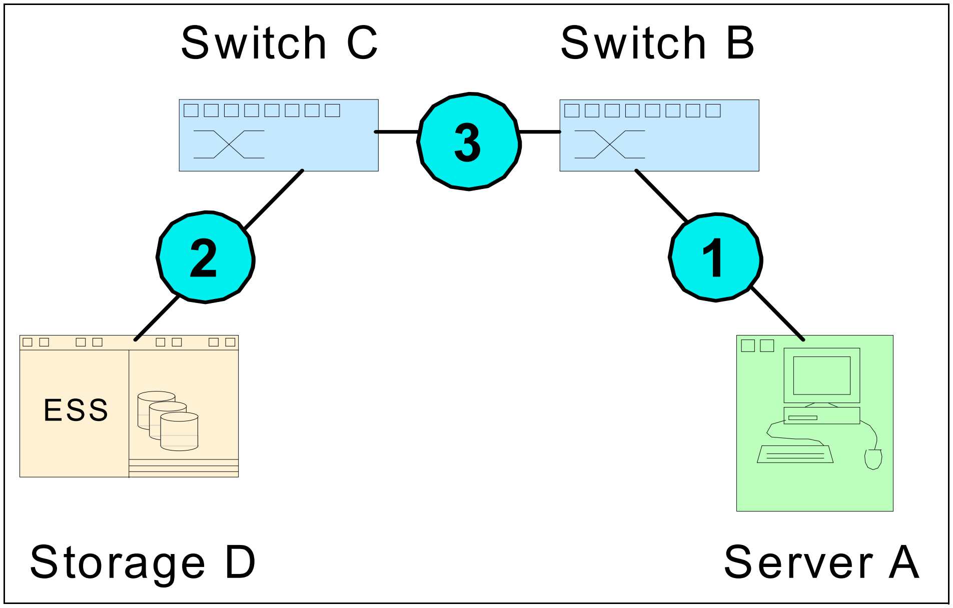


Figure 7-1 A simple fabric

- A fiber optic link problem between server and fabric (at point 1) will give you:
  - A link failure indication at server A
  - A link failure indication at switch B
  - A SCSI failure indication at server A
- A fiber optic link problem between storage and fabric (at point 2) will give you:
  - A link failure indication at storage D
  - A link failure indication at switch C
  - A SCSI failure indication at server A
- An ISL fiber optic link problem between the switches (at point 3) will give you:
  - A link failure indication at switch B
  - A link failure indication at switch C
  - A SCSI failure indication at server A
- An internal SCSI problem in server A or storage D may give you:
  - A SCSI failure indication at server A

As you can see, the internal SCSI failure is the least informative, if there is no further data provided that you can check it against. Rather simple problems may be determined by interpreting just the data of the server for instance, but most likely you'll need to see more than just one side of a connection.

Looking at Figure 7-1 on page 245, you will see there is at least one switch in each link segment from server to storage. Switches are the devices where you will get the most information. The switches are the focal point of SAN management software and switches, as provider of the fabric service, hold most of the vital SAN data: so, switches are the obvious place to look at to perform problem determination (PD) and problem source identification (PSI).

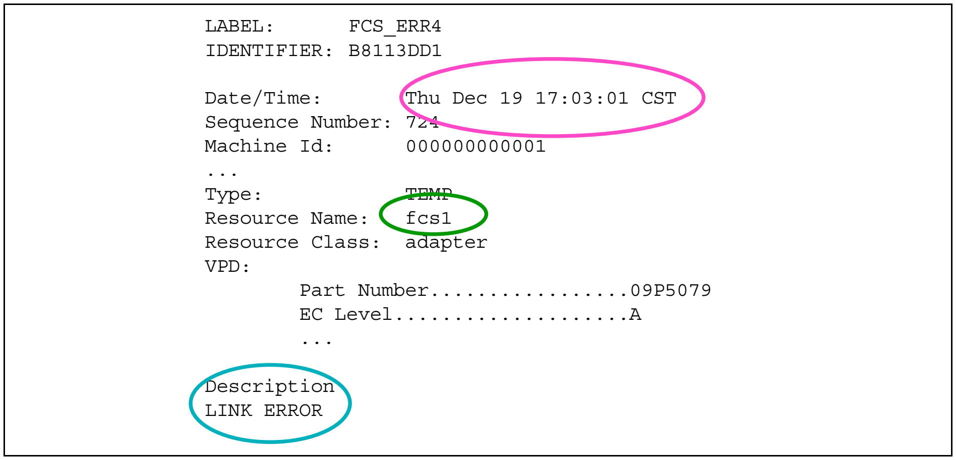
7.3 Where to look for failures

The examples in the following sections have been arbitrarily picked to highlight a particular item. They are not taken from one sample problem.

7.3.1 Connectivity problems

Let's assume you are troubleshooting a connectivity problem between server and storage (it does not matter if it is a new implementation or a failure during normal operation). Depending on the reported fault, you might omit some of the tasks from the list and utilize a different order to us for troubleshooting:

- **Server**
  - Check the event-log and alarm-log (AIX is the example shown in Figure 7-2).



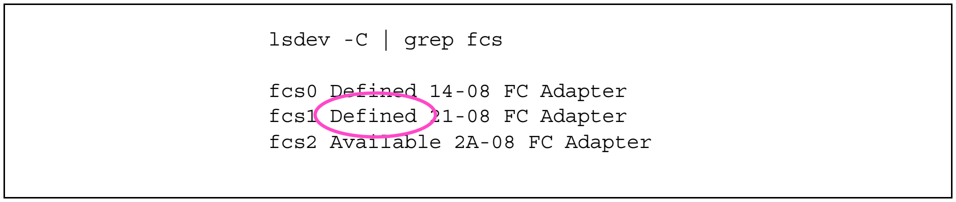
```
LABEL:      FCS_ERR4
IDENTIFIER: B8113DD1

Date/Time:        Thu Dec 19 17:03:01 CST
Sequence Number:  724
Machine Id:       000000000001
...
Type:             TEMP
Resource Name:    fcs1
Resource Class:   adapter
VPD:
        Part Number.................09P5079
        EC Level....................A
        ...

Description
LINK ERROR
```

Figure 7-2 AIX error log

  - Check the status of the system and of the HBAs (pSeries is the example shown in Figure 7-3).

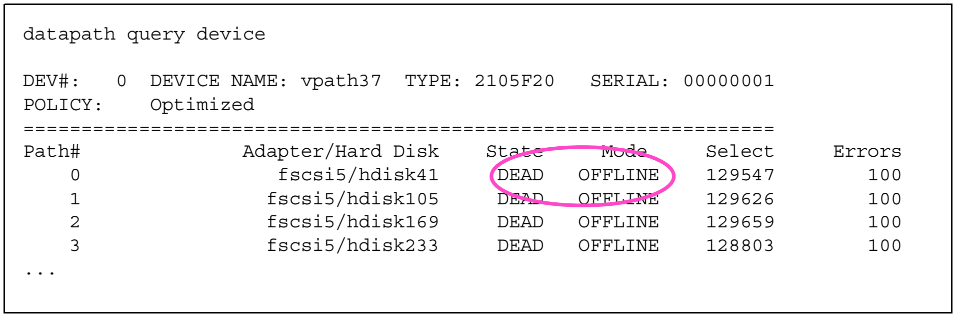


```
lsdev -C | grep fcs

fcs0 Defined 14-08 FC Adapter
fcs1 Defined 21-08 FC Adapter
fcs2 Available 2A-08 FC Adapter
```

Figure 7-3 pSeries HBA status

– If multi-path software is installed, check the virtual paths and adapters (SDD is the example shown in Figure 7-4).



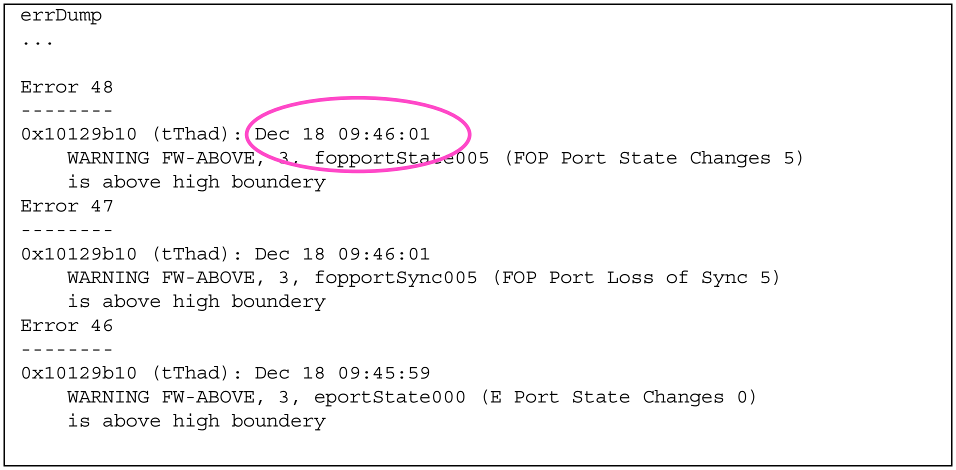
```
datapath query device

DEV#:   0  DEVICE NAME: vpath37  TYPE: 2105F20   SERIAL: 00000001
POLICY:    Optimized
=================================================================
Path#              Adapter/Hard Disk    State     Mode     Select     Errors
    0                 fscsi5/hdisk41     DEAD   OFFLINE    129547        100
    1                fscsi5/hdisk105     DEAD   OFFLINE    129626        100
    2                fscsi5/hdisk169     DEAD   OFFLINE    129659        100
    3                fscsi5/hdisk233     DEAD   OFFLINE    128803        100
...
```

Figure 7-4 SDD information

- **Switches**

  – Check the event and alarm log (2109 in the example shown in Figure 7-5).

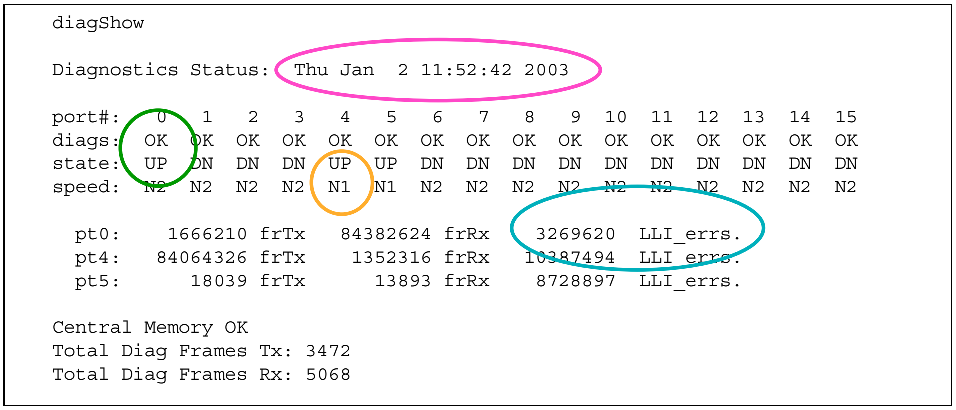


```
errDump
...

Error 48
--------
0x10129b10 (tThad): Dec 18 09:46:01
    WARNING FW-ABOVE, 3, fopportState005 (FOP Port State Changes 5)
    is above high boundery
Error 47
--------
0x10129b10 (tThad): Dec 18 09:46:01
    WARNING FW-ABOVE, 3, fopportSync005 (FOP Port Loss of Sync 5)
    is above high boundery
Error 46
--------
0x10129b10 (tThad): Dec 18 09:45:59
    WARNING FW-ABOVE, 3, eportState000 (E Port State Changes 0)
    is above high boundery
```

Figure 7-5 2109 error log

– Look at the status of the ports to the Fibre Channel device in question and of the ISL ports (2109 is the example shown in Figure 7-6).



```
diagShow

Diagnostics Status:  Thu Jan  2 11:52:42 2003

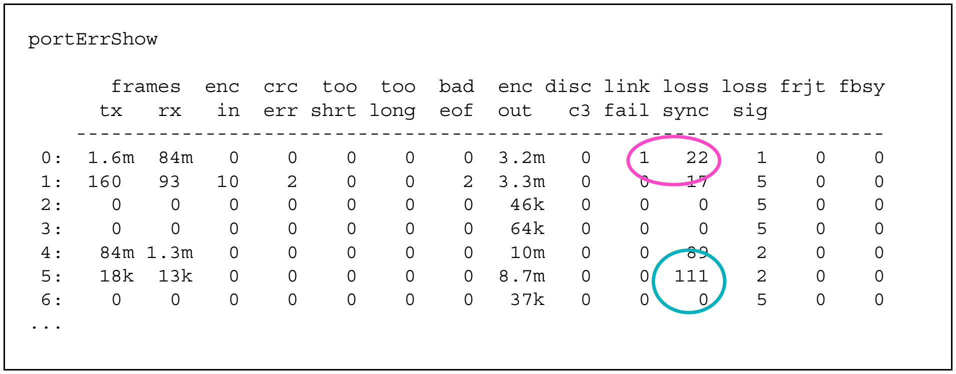
port#:   0   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
diags:  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK  OK
state:  UP  DN  DN  DN  UP  UP  DN  DN  DN  DN  DN  DN  DN  DN  DN  DN
speed:  N2  N2  N2  N2  N1  N1  N2  N2  N2  N2  N2  N2  N2  N2  N2  N2

  pt0:    1666210 frTx   84382624 frRx    3269620  LLI_errs.
  pt4:   84064326 frTx    1352316 frRx   10387494  LLI_errs.
  pt5:      18039 frTx      13893 frRx    8728897  LLI_errs.

Central Memory OK
Total Diag Frames Tx: 3472
Total Diag Frames Rx: 5068
```

Figure 7-6 2109 port diags and status

– Look at the error counter of the ports to the Fibre Channel device in question and of the ISL ports (2109 is the example shown in Figure 7-7).

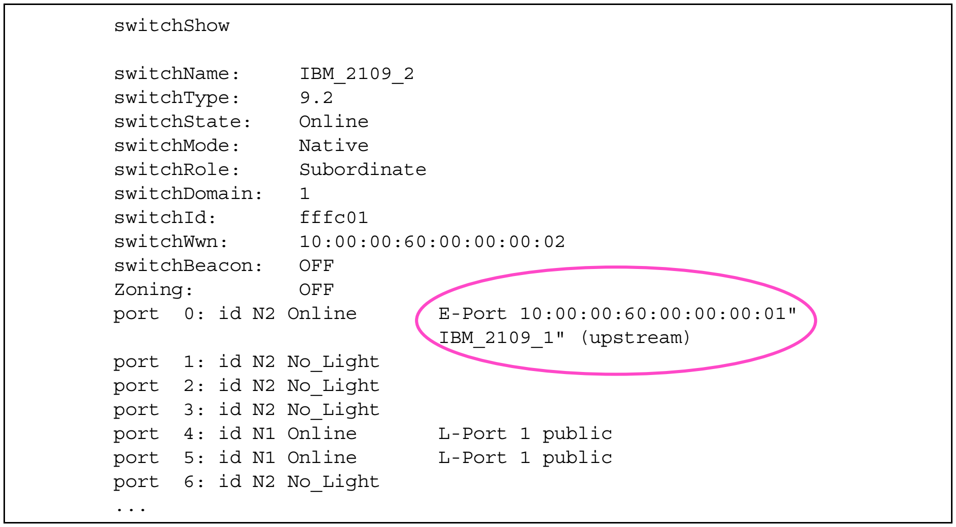


```
portErrShow

       frames  enc  crc  too  too  bad  enc disc link loss loss frjt fbsy
      tx    rx   in  err shrt long  eof  out   c3 fail sync  sig
    ----------------------------------------------------------------------
 0:  1.6m  84m    0    0    0    0    0 3.2m    0    1   22    1    0    0
 1:  160   93    10    2    0    0    2 3.3m    0    0   17    5    0    0
 2:     0    0    0    0    0    0    0  46k    0    0    0    5    0    0
 3:     0    0    0    0    0    0    0  64k    0    0    0    5    0    0
 4:   84m 1.3m    0    0    0    0    0  10m    0    0   89    2    0    0
 5:   18k  13k    0    0    0    0    0 8.7m    0    0  111    2    0    0
 6:     0    0    0    0    0    0    0  37k    0    0    0    5    0    0
...
```

Figure 7-7 2109 port errors

– Check the status of the switch and the integrity of the fabric (2109 is the example shown in Figure 7-8).

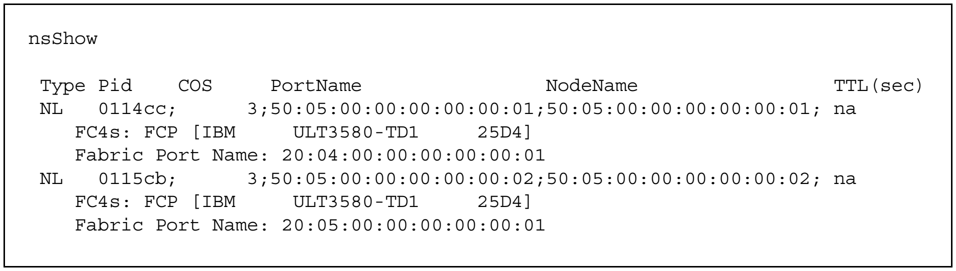


```
switchShow

switchName:     IBM_2109_2
switchType:     9.2
switchState:    Online
switchMode:     Native
switchRole:     Subordinate
switchDomain:   1
switchId:       fffc01
switchWwn:      10:00:00:60:00:00:00:02
switchBeacon:   OFF
Zoning:         OFF
port  0: id N2 Online       E-Port 10:00:00:60:00:00:00:01"
                            IBM_2109_1" (upstream)
port  1: id N2 No_Light
port  2: id N2 No_Light
port  3: id N2 No_Light
port  4: id N1 Online       L-Port 1 public
port  5: id N1 Online       L-Port 1 public
port  6: id N2 No_Light
...
```

Figure 7-8   2109 switch and fabric information

– Check the name server table of the switches to check if the Fibre Channel devices are logged in to the fabric properly (2109 is the example shown in Figure 7-9).



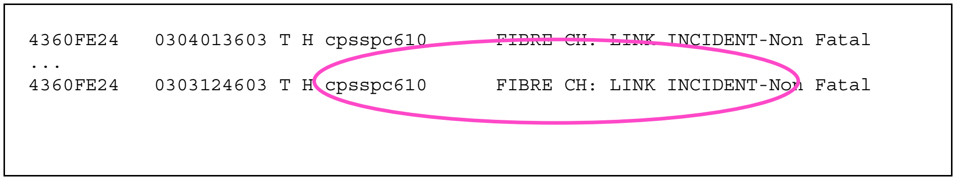
```
nsShow

 Type Pid    COS     PortName                NodeName                 TTL(sec)
 NL   0114cc;      3;50:05:00:00:00:00:00:01;50:05:00:00:00:00:00:01; na
    FC4s: FCP [IBM     ULT3580-TD1     25D4]
    Fabric Port Name: 20:04:00:00:00:00:00:01
 NL   0115cb;      3;50:05:00:00:00:00:00:02;50:05:00:00:00:00:00:02; na
    FC4s: FCP [IBM     ULT3580-TD1     25D4]
    Fabric Port Name: 20:05:00:00:00:00:00:01
```

Figure 7-9   2109 name server table

– Check the integrity of the zoning to make sure that devices have not been isolated and the zoning config that is active, is the one that you expect to be active.

- **Storage**
  - Check the event and alarm log of the Fibre Channel storage (ESS is the example shown in Figure 7-10).



```
4360FE24   0304013603 T H cpsspc610      FIBRE CH: LINK INCIDENT-Non Fatal
...
4360FE24   0303124603 T H cpsspc610      FIBRE CH: LINK INCIDENT-Non Fatal
```

Figure 7-10 ESS error log

  - Check the status of the Fibre Channel ports.
  - Check the volume assignment at the storage device.

Error logs may hold entries from the past few months so make sure you concentrate on the actual fault and do not get lost or side-tracked in all the information. Try to link the errors from the different devices together to follow the trace of the problem through the SAN; information about the components, their location and adjacent devices and/or ports are provided by the logs.

While checking the status of server, switches and storage, note down the OS version and maintenance level, driver level and firmware versions. Don't forget to *save* all this information! You may not find the problem by yourself and you may need to hand it over to other support personnel. In the meantime, some information may already be dropping off the logs or be overwritten by new entries. It is important to see data from each device along the chain from server to storage taken at the same time to get correlated failure information. It also can be of use to have a trace or information from a time when an error was not present, so that it can be compared to the error situation.

Note on preventive action: Make sure all SAN devices run on the same date/time-base, so during PD/PSI, cause and effect of the failure can be clearly correlated.

7.3.2 Performance problems

Different from a pure (and obvious) connection problems (for example a disconnected fiber optic cable) are performance problems. Some possible causes put down to performance may be:

- End-user applications needing more bandwidth than expected
- Lack of available bandwidth due to link degradation

A degraded link or path is a kind of connectivity failure which takes away some of the available bandwidth, such as a partial link out of a trunk, or a complete ISL/trunk, which loads more traffic over the remaining ISLs.

Bit errors and performance

The bit stream of all data traffic in Fibre Channel is validated by a cyclic redundancy check (CRC). The application receiving Fibre Channel frames can trust implicitly that no content has changed due to bad link quality, as the error frames are either corrected or deleted. The Fibre Channel standard limits the maximum bit error rate to “1exp-12”, which means: there must not be more than 1 bit error out of 1exp12 bits in total. According to that value, with a bandwidth of 1Gb/s of your fiber optic link, you may expect no more than 1 bit error each 1000 sec, or about 17 minutes.

This formula is shown in Figure 7-11.

$$t_{err} = \frac{1}{\text{error rate} \times \text{bandwidth}} = \frac{1}{1\,\mathrm{exp}{-12}\left(\frac{b}{s}\right) \times 1\,\mathrm{exp}9\,b} = 1000s$$

Figure 7-11 Bit error formula

Bit errors may happen and may affect the data frames. These data frames will be re-transmitted at the request of the upper-layer protocols. If the link suffers a lot of bit errors, you may experience a slight performance loss.

These bit errors may affect the Receiver Ready (R_RDY) too. A R_RDY is never repeated, so the buffer credit is one BB_Credit short until the link is reset. If your server only had two BB_Credits at the beginning, the server will lose 50% of its credits and may suffer up to 50% performance loss (this will not happen in arbitrated loops where BB_Credits are increased at the start of each loop tenancy).

CRC: Cyclic redundancy check is an single-error correction, and multiple-error detection method. As a 32-bit value, CRC is part of the Fibre Channel frame.

Performance problem troubleshooting

When looking at performance problems, you are aiming to solve a different type of connectivity problem. So, the data sources to look at are the same as before:

- **Server:**
  - Check the event and alarm log.
  - If multi-path software is installed, check the virtual paths and adapters.
- **Switches:**
  - Check the event and alarm log.
  - Monitor performance on the ports to the Fibre Channel device in question and on the ISL ports. If you don't have comparable values preserved to check against, you may need to take two snapshots of the values in an interval of a couple of minutes to see how these values change over time.
  - Check the status of the switch and the integrity of the fabric.
  - Check the integrity of the zoning.
- **Storage:**
  - Check the event and alarm log.
  - Check the status of the Fibre Channel ports.

All this information should give you an idea if there is a bottleneck by design in your SAN, or if a failing component caused that bottleneck. In the former case, perhaps an accepted ISL-oversubscription (refer to 8.7, "Definitions" on page 270) was too high and needs to be adjusted. You will want to collect the performance data for a review and potentially add more paths.

> **Note on preventive action:** Check and save performance profiles at particular times and days to help distinguish performance problems related to design from other ones, such as those occurring in normal peak traffic.

7.4 Other Fibre Channel diagnostic tools

All FC devices come with some kind of diagnostics, which should be used to troubleshoot problems and usually they are described in the devices' product manuals.

There is a saying: "physician, heal thyself" (it may not help too much being a doctor when you are the one who is sick!). Or, to put this another way, how much trust should you place in the failure indications reported by a failing device?

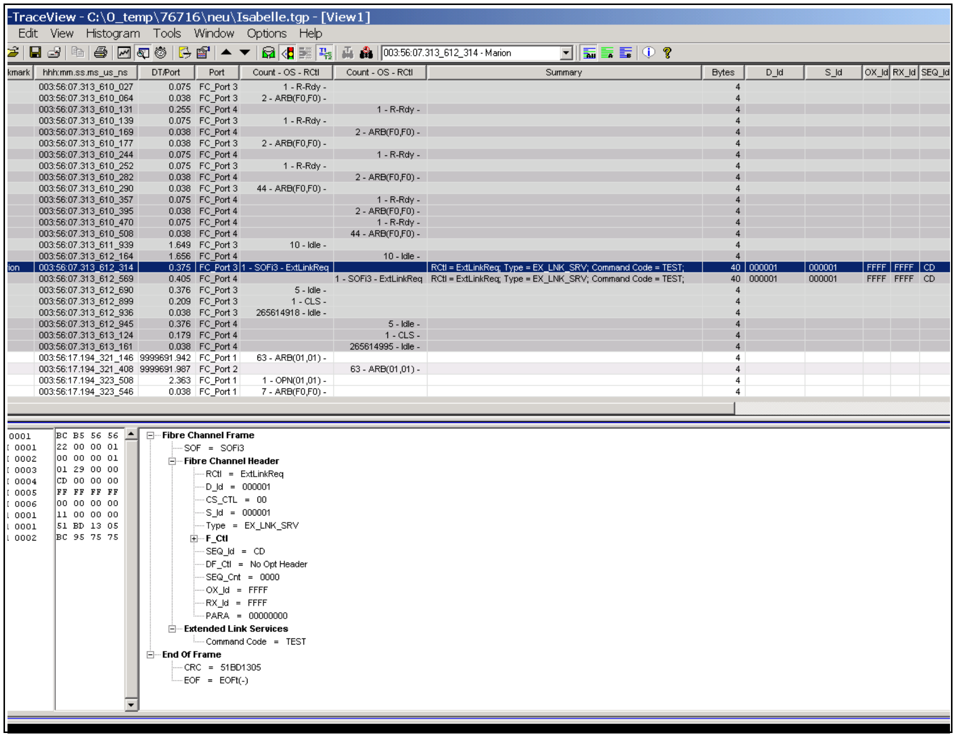
To find out what is really going on, your SAN service provider should be able to delve into the bits and bytes of the Fibre Channel data exchange when looking for protocol violations, time-out problems, and the kinds of failures that may corrupt your data — but that do not typically write to a log. The service provider will do this by using a Fibre Channel analyzer.

There are diverse Fibre Channel protocol analyzing tools (trace tools) on the market, which are able to collect in real-time Fibre Channel frames on 1 Gb/s and 2 Gb/s links, and optionally stop the trace on a triggered event and decode Fibre Channel and upper-layer protocols.

Notes® on preventive action: Look at assigning prepared points for Fibre Channel data interception in your cabling: patch panels and some of the switches provide with splitter or mirror options, so a protocol analyzer can be attached at any time without taking the fiber optic link offline.

The trace tools are designed for the needs of Fibre Channel protocol specialists to look into the details of data exchange and then to determine the cause of a malfunction.

Figure 7-12 and Figure 7-13 show typical decoding screens of two of the most popular Fibre Channel trace tools.

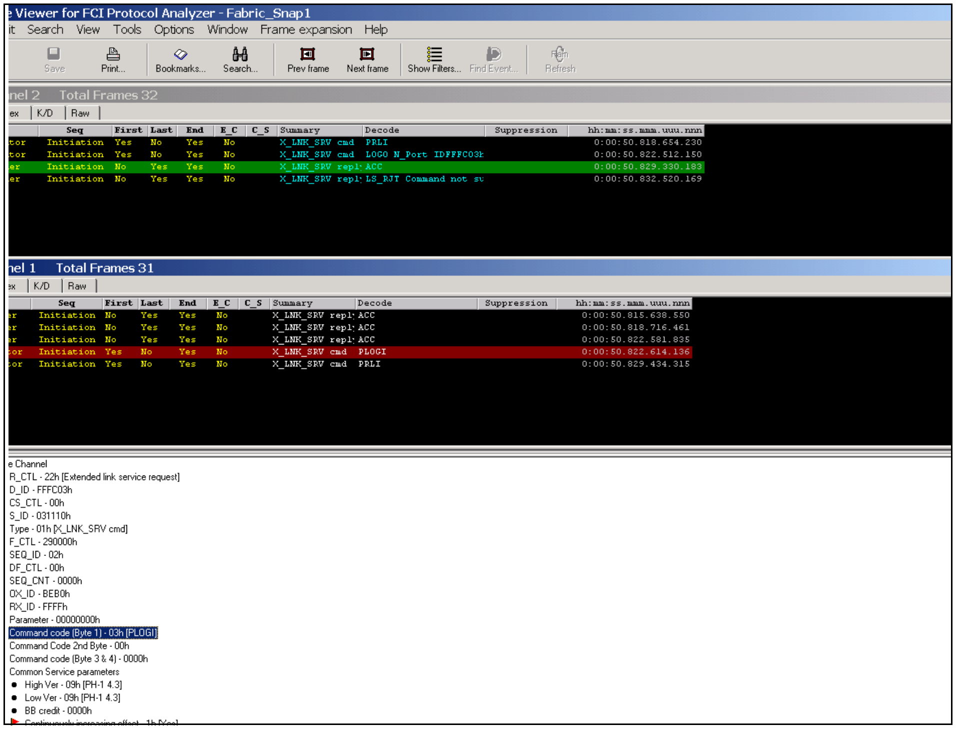

-TraceView - C:\0_temp\76716\neu\Isabelle.tgp - [View1]
Edit
View
Histogram
Tools
Window
Options
Help
003:56:07.313_612_314 - Marion

kmark	hhh:mm.ss.ms_us_ns	DT/Port	Port	Count - OS - RCtl	Count - OS - RCtl	Summary	Bytes	D_Id	S_Id	OX_Id	RX_Id	SEQ_Id
	003:56:07.313_610_027	0.075	FC_Port 3	1 - R-Rdy -			4					
	003:56:07.313_610_064	0.038	FC_Port 3	2 - ARB(F0,F0) -			4					
	003:56:07.313_610_131	0.255	FC_Port 4		1 - R-Rdy -		4					
	003:56:07.313_610_139	0.075	FC_Port 3	1 - R-Rdy -			4					
	003:56:07.313_610_169	0.038	FC_Port 4		2 - ARB(F0,F0) -		4					
	003:56:07.313_610_177	0.038	FC_Port 3	2 - ARB(F0,F0) -			4					
	003:56:07.313_610_244	0.075	FC_Port 4		1 - R-Rdy -		4					
	003:56:07.313_610_252	0.075	FC_Port 3	1 - R-Rdy -			4					
	003:56:07.313_610_282	0.038	FC_Port 4		2 - ARB(F0,F0) -		4					
	003:56:07.313_610_290	0.038	FC_Port 3	44 - ARB(F0,F0) -			4					
	003:56:07.313_610_357	0.075	FC_Port 4		1 - R-Rdy -		4					
	003:56:07.313_610_395	0.038	FC_Port 4		2 - ARB(F0,F0) -		4					
	003:56:07.313_610_470	0.075	FC_Port 4		1 - R-Rdy -		4					
	003:56:07.313_610_508	0.038	FC_Port 4		44 - ARB(F0,F0) -		4					
	003:56:07.313_611_939	1.649	FC_Port 3	10 - Idle -			4					
	003:56:07.313_612_164	1.656	FC_Port 4		10 - Idle -		4					
ion	003:56:07.313_612_314	0.375	FC_Port 3	1 - SOFi3 - ExtLinkReq		RCtl = ExtLinkReq; Type = EX_LNK_SRV; Command Code = TEST;	40	000001	000001	FFFF	FFFF	CD
	003:56:07.313_612_569	0.405	FC_Port 4		1 - SOFi3 - ExtLinkReq	RCtl = ExtLinkReq; Type = EX_LNK_SRV; Command Code = TEST;	40	000001	000001	FFFF	FFFF	CD
	003:56:07.313_612_690	0.376	FC_Port 3	5 - Idle -			4					
	003:56:07.313_612_899	0.209	FC_Port 3	1 - CLS -			4					
	003:56:07.313_612_936	0.038	FC_Port 3	265614918 - Idle -			4					
	003:56:07.313_612_945	0.376	FC_Port 4		5 - Idle -		4					
	003:56:07.313_613_124	0.179	FC_Port 4		1 - CLS -		4					
	003:56:07.313_613_161	0.038	FC_Port 4		265614995 - Idle -		4					
	003:56:17.194_321_146	9999691.942	FC_Port 1	63 - ARB(01,01) -			4					
	003:56:17.194_321_408	9999691.987	FC_Port 2		63 - ARB(01,01) -		4					
	003:56:17.194_323_508	2.363	FC_Port 1	1 - OPN(01,01) -			4					
	003:56:17.194_323_546	0.038	FC_Port 1	7 - ARB(F0,F0) -			4					

```
0001     BC B5 56 56
[ 0001   22 00 00 01
[ 0002   00 00 00 01
[ 0003   01 29 00 00
[ 0004   CD 00 00 00
[ 0005   FF FF FF FF
[ 0006   00 00 00 00
l 0001   11 00 00 00
l 0001   51 BD 13 05
l 0002   BC 95 75 75
```

```
⊟ Fibre Channel Frame
    SOF = SOFi3
  ⊟ Fibre Channel Header
      RCtl = ExtLinkReq
      D_Id = 000001
      CS_CTL = 00
      S_Id = 000001
      Type = EX_LNK_SRV
    ⊞ F_Ctl
      SEQ_Id = CD
      DF_Ctl = No Opt Header
      SEQ_Cnt = 0000
      OX_Id = FFFF
      RX_Id = FFFF
      PARA = 00000000
  ⊟ Extended Link Services
      Command Code = TEST
⊟ End Of Frame
    CRC = 51BD1305
    EOF = EOFt(-)
```

Figure 7-12 FINISAR GTX TraceView



```
     Seq         First Last  End   E_C  C_S  Summary          Decode                      Suppression    hh:mm:ss.mmm.uuu.nnn
tor  Initiation  Yes   No    Yes   No        X_LNK_SRV cmd    PRLI                                        0:00:50.818.654.230
tor  Initiation  Yes   No    Yes   No        X_LNK_SRV cmd    LOGO N_Port IDFFFC03h                       0:00:50.822.512.150
er   Initiation  No    Yes   Yes   No        X_LNK_SRV repl; ACC                                          0:00:50.829.330.183
er   Initiation  No    Yes   Yes   No        X_LNK_SRV repl; LS_RJT Command not su                        0:00:50.832.520.169
```

```
     Seq         First Last  End   E_C  C_S  Summary          Decode                      Suppression    hh:mm:ss.mmm.uuu.nnn
er   Initiation  No    Yes   Yes   No        X_LNK_SRV repl; ACC                                          0:00:50.815.638.550
er   Initiation  No    Yes   Yes   No        X_LNK_SRV repl; ACC                                          0:00:50.818.716.461
er   Initiation  No    Yes   Yes   No        X_LNK_SRV repl; ACC                                          0:00:50.822.581.835
tor  Initiation  Yes   No    Yes   No        X_LNK_SRV cmd    PLOGI                                       0:00:50.822.614.136
tor  Initiation  Yes   No    Yes   No        X_LNK_SRV cmd    PRLI                                        0:00:50.829.434.315
```

```
e Channel
R_CTL - 22h [Extended link service request]
D_ID - FFFC03h
CS_CTL - 00h
S_ID - 031110h
Type - 01h [X_LNK_SRV cmd]
F_CTL - 290000h
SEQ_ID - 02h
DF_CTL - 00h
SEQ_CNT - 0000h
OX_ID - BEB0h
RX_ID - FFFFh
Parameter - 00000000h
Command code (Byte 1) - 03h [PLOGI]
Command Code 2nd Byte - 00h
Command code (Byte 3 & 4) - 0000h
Common Service parameters
 ● High Ver - 09h [PH-1 4.3]
 ● Low Ver - 09h [PH-1 4.3]
 ● BB credit - 0000h
 ▶ Continuously increasing offset - 1h [Yes]
```

Figure 7-13 Xyratex FCI Protocol Analyzer

Although most of these trace tools offer expert functions, which go through the whole trace data and search for FC protocol violations and obvious matters between the FC devices like open requests, the tool itself is not always able to find the problem on its own. It still requires a specialist to analyze it.

More information about these vendors trace tools can be found at these Web sites:

http://www.finisar.com/home/
http://www.xyratex.com/

Part 2

Survival solutions

“My mind rebels at stagnation. Give me problems, give me work, give me the most abstruse cryptogram, or the most intricate analysis, and I am in my proper atmosphere. I can dispense then with artificial stimulants. But I abhor the dull routine of existence. I crave for mental exaltation.”

Sherlock Holmes.

Not wishing to let our minds stagnate, in the second part of this book, we offer some SAN survival solutions. Obviously it is not possible for us to describe every possible solution that exists; however, we will show how we have employed the components, features, and disciplines to suit our environment.

8

General solutions

In this chapter we discuss some of the building blocks and general concepts for building reliable and powerful SANs. Included are requirements for servers and storage and their software, as well as fabric devices.

We present various implementations and uses of a SAN environment, starting with a simple fabric and building it up into a complex design.

8.1 Objectives of SAN implementation

To ensure the highest level of system uptime, utilization, and security, companies are implementing reliable storage networks capable of boosting the availability of data for all the users and applications that need it. These companies typically represent the industries that demand the highest levels of system and data availability — the utilities and telecommunications sector, brokerages and financial service institutions, and a wide variety of service providers.

By reducing or eliminating single points of failure in the enterprise environment, SANs can help to improve overall availability of business applications. By utilizing highly available components and secure solutions as well as a fault-tolerant design, enterprises can achieve the availability needed to support 24x7 uptime requirements.

In vital networks such as SANs, with their associated hosts, fabric, and storage components, as well as software applications, downtime can occur even if parts of the system are highly available or fault tolerant. To improve business continuance under a variety of circumstances, SANs can incorporate redundant components, connections, software, and configurations to minimize or eliminate single points of failure.

Implementing multiple levels of redundancy throughout a SAN environment can reduce down-time by orders of magnitude. For instance, hardware components, servers, storage devices, network connections, and even the storage network itself can be completely redundant. A fundamental rule for improving fault tolerance is to ensure multiple paths through separate components regardless of a vendor's assurances of high availability. This is especially true when physical location and disaster tolerance are concerns, or when a complex device can become a single point of failure.

8.2 Servers and host bus adapters

To ensure availability, hosts should include redundant hardware components with dual power supplies, dual network connections, and mirrored system disks typically used in enterprise environments. Hosts should also have multiple connections — two independent connections is a minimum — to alternate storage devices through Fibre Channel switches. In most cases, servers should feature dual-active or hot-standby configurations with automatic failover capabilities.

8.2.1 Path and dual-redundant HBA

The next single point of failure to consider after the server is the path between the server and the storage. Potential points of failure on this path might include HBA failures, cable issues, fabric issues, or storage connection problems. The HBA is the Fibre Channel interconnect between the host and the SAN (replacing the traditional SCSI card for storage connectivity). Using a dual-redundant HBA configuration helps ensure that a path is always available. In addition to providing redundancy, this configuration will enable overall higher performance due to the additional SAN connectivity.

8.2.2 Multiple paths

To achieve fault tolerance, multiple paths are connected to alternate locations within the SAN or even to a completely redundant SAN. Server-based software for path failover enables the use of multiple HBAs, and typically allows a dual-active configuration that can divide workload between multiple HBAs — improving performance. The software monitors the “health” of available storage, servers, and physical paths and automatically reroutes data traffic to an alternate path if a failure occurs.

Path failover

In the event of an HBA or link failure, the host software detects that the data path is no longer available and transfers the failed HBAs workload to an active one. The remaining HBA then assumes the workload until the failed HBA is replaced or the link is repaired. After identifying failed paths or failed-over storage devices and resolving the problem, the software automatically initiates fail back and restores the dual path without impacting applications. If desired, an administrator can manually perform the fail back to verify the process.

The software that performs this failover is typically provided by system vendors, storage vendors, or value-added software developers. Software solutions, such as IBM Subsystem Device Driver (SDD), help ensure that data traffic can continue despite a path failure. These types of software products effectively remove connections, components, and devices as single points of failure in the SAN to improve availability of enterprise applications.

To help eliminate unnecessary failover, the software distinguishes between actual solid failures and temporary network outages that might appear to be solid failures. By recognizing false failures, the software can help prevent unnecessary failover/fallback effects caused by marginal or intermittent conditions. After detecting an actual failure, the software typically waits to determine whether the event is an actual failure.

The typical delay in the failover process can range from an instant failover (when a loss of signal light is detected) up to a minute (if the light signal is still available and the path failure is in another part of the network). These delays are typically adjustable to allow for a variety of configurations and to allow other, more rapid recovery mechanisms such as path rerouting in the SAN.

8.3 Software

One of the keys to improving availability is shifting the focus from server availability and recovery to application availability and recovery. Mission-critical applications should be supported on clustered or highly available servers and storage devices to ensure the applications' ability to access data when they need it — even in the midst of a failure. Sophisticated software applications can enable application or host failover, in which a secondary server assumes the workload if a failure occurs on the primary server. Other types of software, such as many database applications, enable workload sharing by multiple servers — adding to continuous data availability where any one of several servers can assume the tasks of a failed server.

In addition, many server vendors and value-added software providers offer clustering technology to keep server-based applications highly available, regardless of individual component failures. The clustering software is designed to transfer workload among active servers without disrupting data flow. As a result, clustering helps companies guard against equipment failures, keep critical systems online, and meet increased data access expectations.

Some clustering software, such as VERITAS Cluster Server, enables application failover on an application by application basis. This capability enables administrators to prioritize the order of application failover. Fibre Channel SANs facilitate high-availability clustering by simplifying storage and server connectivity. Moreover, SANs can provide one of the most reliable infrastructures for server clustering, particularly when clustered servers are distributed throughout the enterprise to achieve higher levels of disaster tolerance, a practice known as "stretched clusters."

8.4 Storage

To improve performance and fault tolerance, many of today's storage devices feature multiple connections to the SAN. Multiple connections help guard against failures that might result from a damaged cable, failed controller, or failed SAN component, such as an SFP optical module. The failover process for storage connections typically follows one of the following methods.

Transparent failover

One method is transparent failover, in which a secondary standby connection comes online if the primary connection fails. Because the new connection has the same address as the original failed connection, failover is transparent to the server connection, and application performance is not affected. After the primary connection is repaired, it assumes the workload.

Active connections

Another method is to use dual or multiple active connections with each connection dedicated to certain logical volumes within a given storage system. If one connection fails, the other active connections automatically assume its logical volume workload until it comes back online. During this time, the alternate connections support all logical volumes, so there might be a slight performance impact depending on workload and traffic patterns.

Load balancing connections

A third method used for storage path failover also utilizes dual or multiple active connections. In this case, however, both connections can simultaneously access the logical volumes. This design can improve performance through load balancing, but typically requires host-based software.

During a storage connection failure, the alternate active connection continues to access the logical volumes. After the failed connection is repaired, the other path becomes active and load balancing resumes.

All of these failover methods are designed to ensure the availability of the enterprise applications that use them. In addition, failover generally is coordinated with server software to ensure an active path to data, transparent to the application.

Mirroring

Another effective way to achieve high availability in a SAN environment is by mirroring storage subsystems. SANs enable efficient mirroring of data on a peer-to-peer basis across the fabric.

These mirroring functions contribute tremendous fault tolerance and availability characteristics to SAN-based data. Combining the mirroring functions with switch-based routing algorithms (which enable traffic to be routed around path breaks within the SAN fabric) creates a resilient, self-healing environment to support the most demanding enterprise storage requirements. The mirrored subsystems can provide an alternate access point to data regardless of path conditions.

A common use of mirroring involves the deployment of remote sites within the enterprise. Implementing SANs through Fibre Channel switches enables the distribution of storage and servers throughout a campus, metropolitan area, and beyond. Fibre Channel overcomes many of the distance limitations of traditional SCSI connections, enabling devices to be extended over much longer distances for remote mirroring, tape backup, and disaster recovery operations.

8.5 Fabric

The switched fabric, as the central part of the SAN, is the focus of any discussion about performance and availability. The fabric design should provide a high performing environment for all storage-related enterprise applications and ensure connectivity even during partial outages. By implementing redundancy, the fabric design helps to prevent isolated failures from causing widespread outages and minimizes disruption to system operations.

8.5.1 The fabric-is-a-switch approach

Typically, when one thinks of a director, the assumption is that all the fabric redundancy is consolidated into one box. Theoretically, a director is supposed to provide full internal redundancy. Numbers of critical field replaceable units (FRUs) installed in a director will failover automatically should a component malfunction.

High availability is provided through the hardware and options, such as these:

- Redundancy of all active components
- All active components providing support for automatic failover
- Redundant power and cooling
- Hot swapping of all FRUs
- Hot swapping of spare ports
- Automatic fault detection and isolation
- Non-disruptive firmware updates

An example of this approach is shown in Figure 8-1.

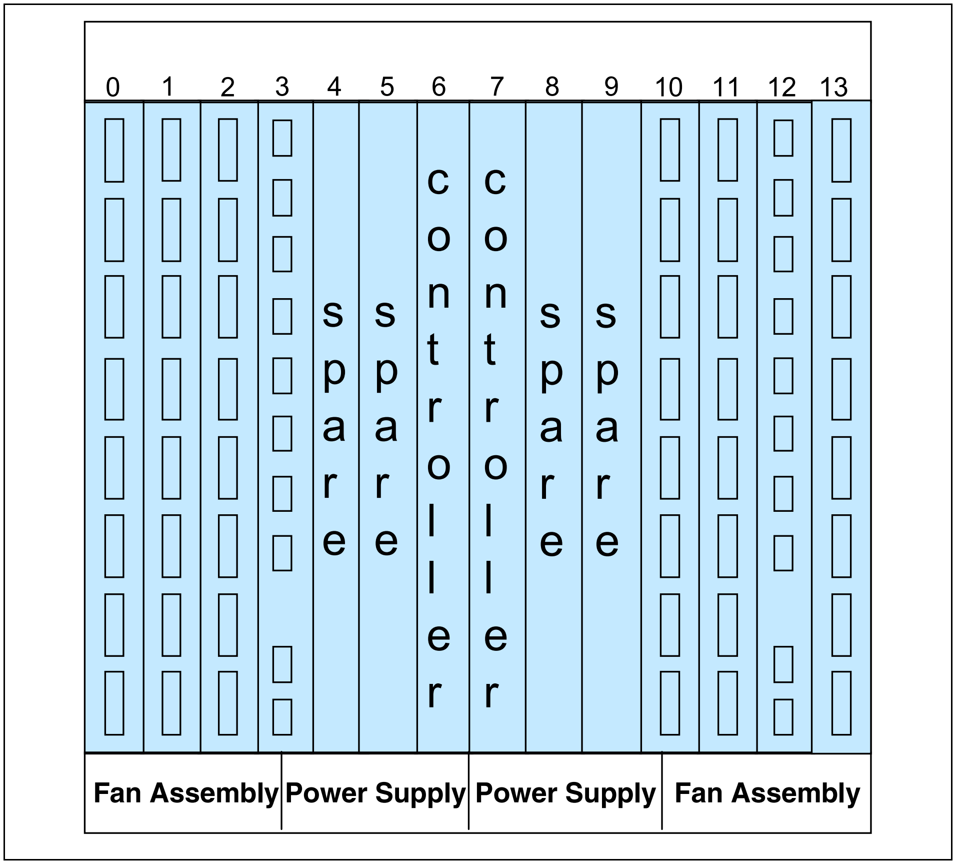


Figure 8-1 Fabric in a director

A director also has a high port density in a single footprint and can usually scale up to an even higher port count. You may build your fabric by implementing one director and have a highly performing and highly available fabric. From a security point of view, a single director is easier to handle and to protect than a widespread fabric, but there is still one single point of failure left, which is the fabric (director) itself. Intentionally or by user error, a fabric can be taken down and therefore the fabric or director should have a backup of its own: a dual fabric.

8.5.2 The fabric-is-a-network approach

Redundancy in the SAN fabric can be built through a network of switches to provide a robust mission-critical SAN solution. With its connected servers, switches, and storage ensuring high availability, the meshed fabric provides a most resilient infrastructure. With an infrastructure of switches, SAN administrators will scale their network to guarantee performance, availability and security by building it into the network rather than relying on a single footprint.

SAN infrastructures require high availability and a high port aggregation to solve problems such as backup and storage consolidation. Since ISLs can be utilized most efficiently nowadays, a network of smaller switches may enable the SAN to support the appropriate level of bandwidth by increasing the number of switches and can be considered as an opposite strategy to the pure director-based SANs.

However, there is no design that is without a limit. To provide every server in the SAN with the appropriate bandwidth to exchange data with its storage, all at the same time, is not a feasible concept. It would mean having to provide ISL bandwidth for the cumulative server port bandwidth, or in other words, to give each server its own dedicated ISL — but that is not in the spirit of networking. Ideally, a network should be oversubscribed to the maximum point possible, while maintaining the minimum acceptable performance.

This approach ensures that the fewest resources can support the greatest numbers of users or applications. A typical oversubscription ratio will be 7:1 or higher to start with. During operation you will observe port performance and decide whether to implement more ISLs or more device ports. By taking advantage of the scalability of the SAN switches and ISL trunking features, the switched fabric can be tailored very easily at the first and subsequent implementations.

8.6 High level fabric design

You can configure scalable solutions that help address your needs for high performance and availability for environments ranging from small workgroups to very large, integrated enterprise SANs.

If you start with a single switch, you will find that when your fabric grows, you will need to connect new switches to it. The first step may be a cascaded design. We show two possible options in Figure 8-2.

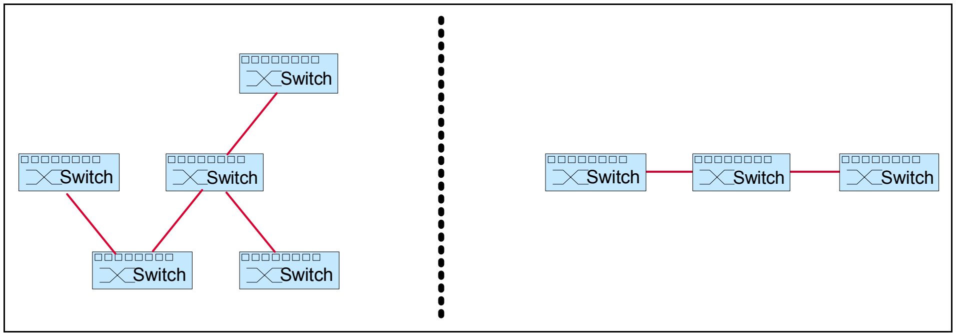


Figure 8-2 Two examples of switch cascading

When cascading switches you will need *(n-1)*-ISLs to connect *n*-switches. It raises your port rate compared to using one switch. With a cascaded fabric it is possible to introduce a bottleneck when traffic has to travel down the ISLs. For this reason there are many ways to ensure that you do not introduce a bottleneck into the SAN.

A next step towards higher performance and higher availability is a ring design, as shown in Figure 8-3.

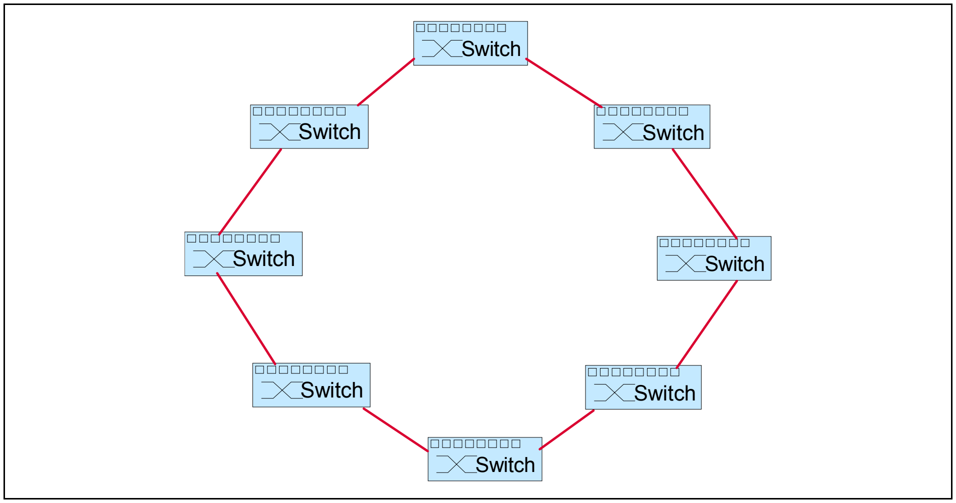


Figure 8-3 Ring design

Whenever one ISL fails, there is still connectivity throughout the whole fabric. However, if an ISL fails, then it may take more hops for the initiator to reach the target. To connect *n*-switches, you'll need *n*-ISLs.

However, these SAN designs do not show very much thought or structure to support the traffic flow. We could dedicate switches to be connected to storage or host only, but all the traffic would have to pass through the ISLs and this may be counter-productive. Also, simply structuring the SAN by dedicating switches to diverse departments will not increase performance nor availability.

The way to increase performance and availability in a fabric is to build a network of switches in a meshed network topology, as shown in Figure 8-4.

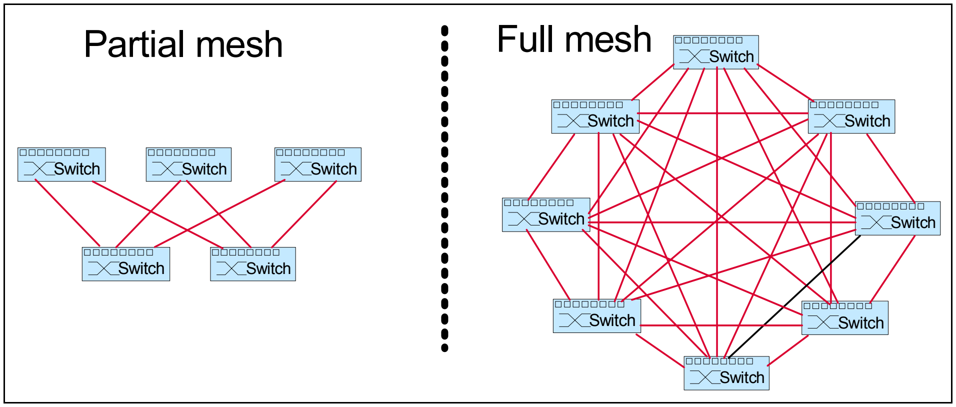


Figure 8-4 Meshed network design

Figure 8-4 shows a partial mesh and full mesh fabric design. For a partial mesh fabric, you will need at least *n*-ISLs to connect *n*-switches. For a full mesh fabric, you will need *m*-ISLs to connect *n*-switches, as follows:

$$m = \frac{n^2 - n}{2}$$

The number of ISLs increases very quickly when the count of switches increases. A full mesh network offers the highest performance and availability.

With either type of meshed topology, it is easy to structure the fabric for the sake of easier maintenance and administration, fault isolation, and higher traffic flow.

A common structure is a tier-layer design with a dedicated layer of switches for hosts and a layer for storage devices, as shown in Figure 8-5.

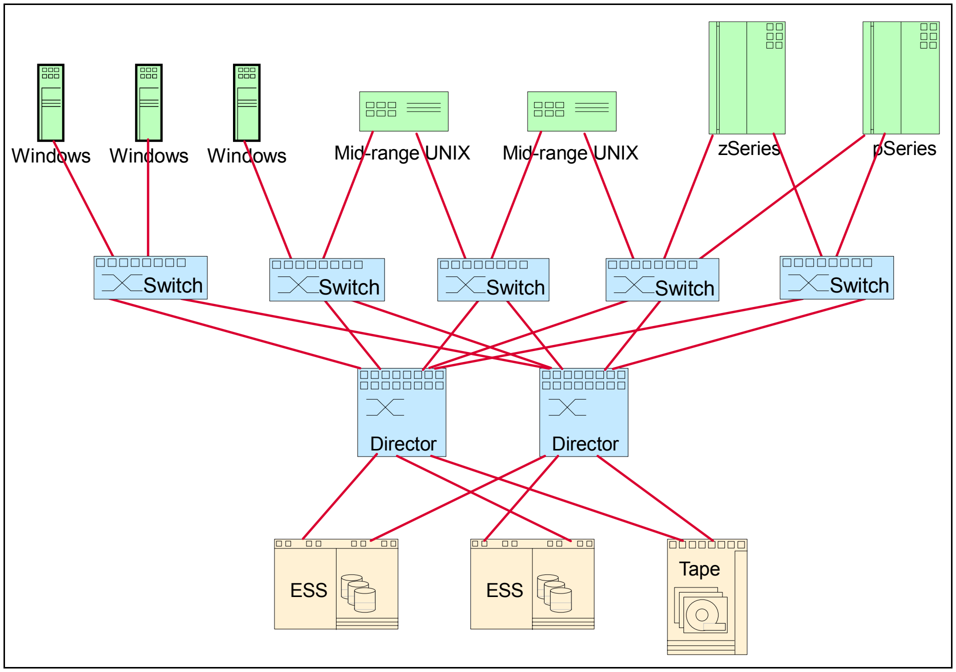


Figure 8-5 Host-tier and storage-tier

It is a partial mesh design with all hosts connected to the upper tier, and all storage devices to the lower one. Every data transfer from host to storage will cross the ISLs and we have to keep that in mind when provisioning the ISLs.

If the SAN were to grow bigger and there were eight switches in each tier, in order to connect every switch in the host-tier to every switch in the storage tier, this would cost 128 ISL ports, as shown in Figure 8-6.

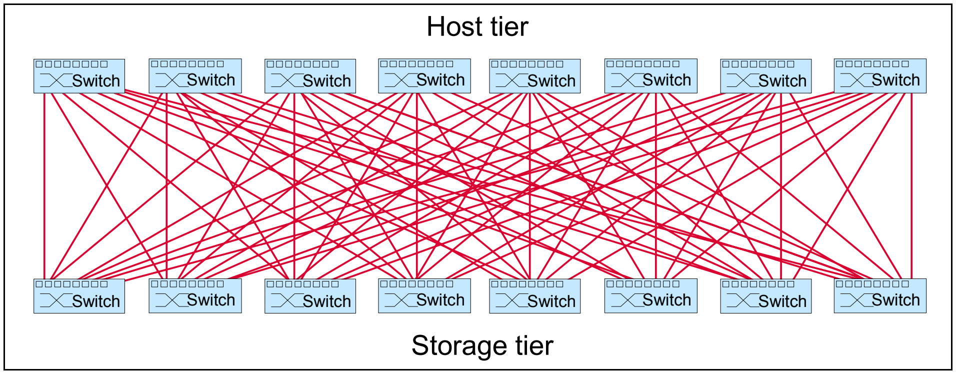


Figure 8-6 Tier to tier

This is just done to single-connect the switches from one tier to the other. The fabric does not gain any higher availability by such a design.

A better way to connect the tiers would be to introduce a “focal point” for all ISLs between the tiers, called core switches; the switches at the host and storage tier are called edge switches. We now have a core-edge design like that shown in Figure 8-7.

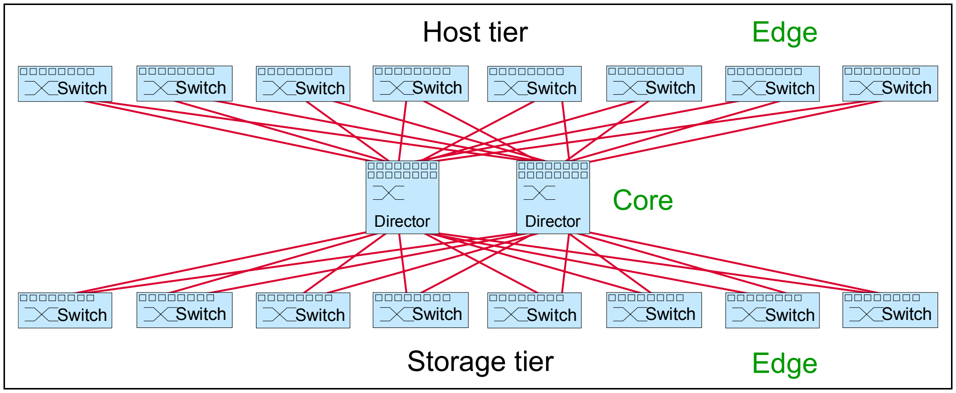


Figure 8-7 Core-edge design

With the core-edge design, you will have any-to-any edge-switch connectivity without having to connect any-to-any switch. We do have less cumulative ISL bandwidth in the SAN now, when compared to the design in Figure .

As the core is the focal point, you will want to deploy your core switches or directors that have redundancy inherent in their design. A storage-tier usually needs less ports than a host-tier. So, in some cases, when your storage devices are pooled locally, you don’t build up a separate edge-tier for storage, as shown in Figure 8-7. Rather, the ports of the core switches connect to the storage devices directly, as shown in Figure 8-5.

8.7 Definitions

In our examples in this chapter and in the following chapters, we will use the following terms:

- **Oversubscription:** This term means the ratio of the number of input devices weighted by their individual bandwidth to the number of output devices also weighted by their individual bandwidth. That may be the amount of hosts connecting to a storage device. For example, a storage device can handle up to 100 MB/s on one port, connecting four servers which will do 60 MB/s each will give us an oversubscription of 2.4:1:

$$oversubscription = \frac{\sum port_{\mathrm{input}} \times bandwidth}{\sum port_{output} \times bandwidth} = \frac{4 \times 60\mathrm{MB/sec}}{100\mathrm{MB/sec}} = \frac{24}{10}$$

- **ISL-oversubscription:** This special case of oversubscription takes the ratio of host ports to the possible ISLs carrying that traffic - again we take bandwidth of the individual ports into account. ISL-oversubscription is of interest in a meshed fabric. The higher the ratio is, the more devices will share the same ISL and the more is it likely we will suffer from congestion. Adding a 2 Gb/s ISL (that is 200 MB/s) to our previous example will give us a value of 1.2:1:

$$\text{ISL-oversubsription} = \frac{\sum port_{\mathrm{input}} \times bandwidth}{\sum ISL \times bandwidth} = \frac{4 \times 60\mathrm{MB/sec}}{200\mathrm{MB/sec}} = \frac{240}{200}$$

Note: If all ports on the switches are operating with the same speed, it is a simple division to calculate ISL-oversubscription. In cases where ports with 2 Gb/s and 1 Gb/s are intermixed, each host port and each ISL has to be multiplied by its bandwidth before computing the ratio.

- **Fan-out:** This is the ratio of server ports to a connected storage port. Fan-out differs from oversubscription in that it represents a ratio based on the number of connections regardless of the throughput. Our previous example would result in a fan-out of 4:1:

$$\text{Fan-out} = \frac{\sum port_{\mathrm{host}}}{\sum port_{storage}} = \frac{4}{1}$$

- **Topology:** This is a synonym for design in networking. Fibre Channel historically supports only three topologies: point-to-point, arbitrated loop, and switched fabric, but this is *not* what is meant here. Topology in our solutions means the design itself of the switched fabric and whether it is a cascaded, meshed, tiered, or a core-edge design.

8.7.1 Port formulas

As we have stated already, oversubscription is an accepted bottleneck. Depending on the load profile of your Fibre Channel devices, you will accept these bottlenecks in such a way that they will never allow the SAN to end up in gridlock.

Typically the first implementation of a SAN is based on assumptions. By using this port formula, you may estimate how many host ports you will get out of a two-tier fabric with a given number of switch ports, and estimated values for host-to-storage oversubscription ($over_{hs}$) and ISL-oversubscription ($over_{ISL}$):

$$\sum port_{host} = \frac{\sum port_{fabric} - \sum port_{spare}}{1 + \frac{1}{over_{hs}} + \frac{2}{over_{ISL}}}$$

As an example, we will use the diagram Figure 8-5 on page 269. We will take seven 32-port switches and assume that we want to use only 80% of the ports in our first implementation, saving the other 20% for future expansions. We will assume a host-to-storage oversubscription of 6:1 and an ISL-oversubscription of 10:1. This is shown in Example 8-1.

Example 8-1 Host-to-storage oversubscription

```
5 switches with 32 ports each: portfabric = 160
20% spare ports: portspare = 32
oversubscription host-to-storage: overhs = 6:1
ISL-oversubscription: overISL = 10:1
```

$$\sum port_{host} = \frac{\sum port_{fabric} - \sum port_{spare}}{1 + \frac{1}{over_{hs}} + \frac{2}{over_{ISL}}} = \frac{160 - 32}{1 + \frac{1}{6} + \frac{2}{10}} = 93$$

```
So:
The host ports come to: porthost = 93
The storage ports will be portstorage (93 / 6) = 15
The ISLs will be (93 / 10) = 10, which is 20 ISL ports
```

The assumptions about oversubscription in the previous example will delegate the used ports of the fabric to 73% as host ports, 12% as storage ports, and 15% as ISL ports.

You can use that formula for a core-edge design too (see Figure 8-7 on page 270). If you ignore the core ports and just count the ports of your edge-switches to get $\Sigma port_{fabric}$, simply calculate the other port counts and assume that your core ports are the same value as the ISL ports. So, referring back to Example 8-1 on page 272, your core would consist of another 20 ISL ports.

8.8 Our solutions

In the following chapters we categorize and discuss the relevant items of SAN design in various implementations with different switches and directors. We have categorized the solutions according to:

- Performance
- Availability
- Distance
- Clustering
- Secure

We have also added any vendor specific and unique solutions. Although we categorize, for example, a solution as a *performance* solution, this does not mean that it is only a performance solution. It will typically contain elements of all the other categories as well, but we have just chosen to focus on one aspect for clarity. A *Checklist* and *“What If” failure scenario* complements each solution.

9

IBM TotalStorage switch solutions

In this chapter we present implementations of IBM Fibre Channel switches in diverse environments. The solutions are categorized as follows:

- Performance solutions
- Availability solutions
- Distance solutions
- Clustering solutions
- Secure solutions
- Loop solutions

9.1 Performance solutions

When there is little or no server performance information available, it is difficult to work out the ratio of server ports to storage ports. Figure 9-1 illustrates how a general high performance profile could be applied to a SAN design using eight 2109-F16 switches and a single ESS. In Figure 9-1, for greater clarity, we show only the dual connections of the first 12 hosts to the switches.

Each switch is connected to 12 servers and to two ESS ports, one ISL for zoning information propagation, and one as a spare. This methodology should only be used to generate a high level design. Final designs must be based on performance data collected from the servers.

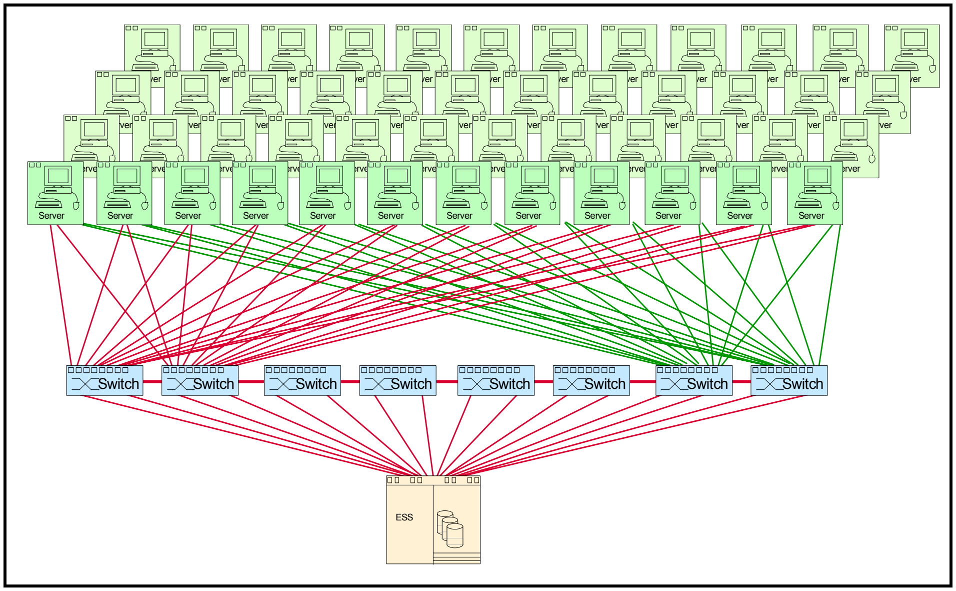


Figure 9-1 High performance single-tier redundant fabric

Components

- SAN fabric
  - Eight 2109-F16 switches
- Servers:
  - 48 servers each configured with dual FC HBAs
- Storage:
  - One ESS 2105-800 with 16 FC Adapters
- Software:

  IBM Subsystem Device Driver (SDD)

Checklist

- Install and configure switches.
- Install Fibre Channel Host Bus adapters.
- Configure ESS.
- Attach ESS to switch.
- Attach servers to switch.
- Validate failover/failback operations.
- List of firmware/drivers, revisions of servers, HBA, and storage.

Performance

Typically, an ESS FC adapter will operate at up to 130 MB/s. We have configured 16 connections from the fabric to the ESS, and have a maximum SAN peak bandwidth capability of 2080 MB/s (16 x 130 MB/s).

If we connected 48 dual attach servers to the fabric, and all servers were processing at the same time, we would potentially have a maximum SAN peak bandwidth of 43.3 MB/s per server (2080 MB/s / 48). This throughput assumes that all 48 servers are able to generate this level of I/O at the same time.

For our optimal performance configuration, we will utilize all 16 ports in the ESS, and based on our predefined server to storage oversubscription, 48 high performance servers with dual connections to be connected to 16 ESS ports over eight F16 switches. This gives us a server port to storage port oversubscription of 6:1 (96 / 16). This could be categorized as a *high performance profile*.

For *low performance profiles*, such as file and print servers, we use a rule-of-thumb of 12 server connections to one ESS port. In other words, we would use a ratio of 12:1.

To correctly utilize and categorize tape devices, you must take into consideration various functions such as serverless backup, and/or the servers to which the tape device is connected.

Our profile ratios are recommended as a starting point when there are no server performance details available. These rules are very generic and should only be applied at the initial design stage. Prior to any final design, a detailed performance profile should be conducted using open systems performance measuring tools such as IOMETER and IBM Disk Magic.

Scalability

The foregoing configuration is optimized at a 6:1 ratio based on full utilization of the ESS ports. The eight 2109-F16s provide 128 ports; 48 dual servers use 96 ports, seven ISLs to connect adjacent cascaded switches for zoning information propagation (uses 14 ports) and the ESS uses 16 storage ports. So, only two ports are left spare in the whole fabric: this design is at its upper limit. You may enlarge the network by replacing the 2109-F16 by the 32-port 2109-F32 as you need more ports and stay with the same design principles.

Availability

This design provides a higher-availability than for a single director solution as a failure of one or even multiple switches does not necessarily stop server to storage connectivity. Although a failure in the SAN fabric could result in all hosts losing access to the devices. For example, if an invalid zoning change was made to the fabric, or the fabric configuration was corrupted, this would affect all devices in the SAN.

Security

The ESS performs LUN masking by default so all devices with LUNs defined have two levels of security, LUN masking and zoning. Zoning configuration in the switches separates every host FC port from each other, or may gather groups of servers running common operating system or servers belonging to the same department. To guard against unauthorized maintenance access, the switches passwords have been changed from the default.

“What If” failure scenarios

Here we consider the following scenarios:

- **Server HBA:** If one of the HBAs fails, IBM SDD software will automatically failover the workload to the alternate HBA. The server will lose up to 50% of the server SAN bandwidth. Once you have replaced the HBA, you will need to redefine the WWN for the HBA.
- **Cable:** If a cable between a server and the switch fails, IBM SDD software will automatically failover workload to the alternate path. The server SAN performance will be degraded by up to 50%.
- **Cable:** If a cable between the switch and the disk storage fails, the alternate route will be used. The overall SAN performance will degrade by up to 6.25%. On the servers connected to the affected switch, the SAN performance impact will be up to 50%. Servers connected to other storage will not be affected.
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable GBIC.

- **Switch power supply:** Another redundant power supply may be added to the switch, and should one fail, the other will take over automatically.
- **Switch:** If a switch fails, the server will use the alternate switch to connect to the disk storage. The overall SAN performance will degrade by 12.5%, and the servers connected to the switch will be affected by up to 50%. Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID.
- **Storage:** If the ESS fails, the servers will not be able to access the storage. A redundant ESS may be added to mirror data from the primary ESS, or data may be restore from a tape subsystem device.

9.2 Availability solutions

The focus of this topic is on the availability aspect of solutions.

9.2.1 Single fabric

In Figure 9-2 we show a single fabric, two-chassis 2109-M12 core with 2109-F16 and 2109-M12 edge solution.

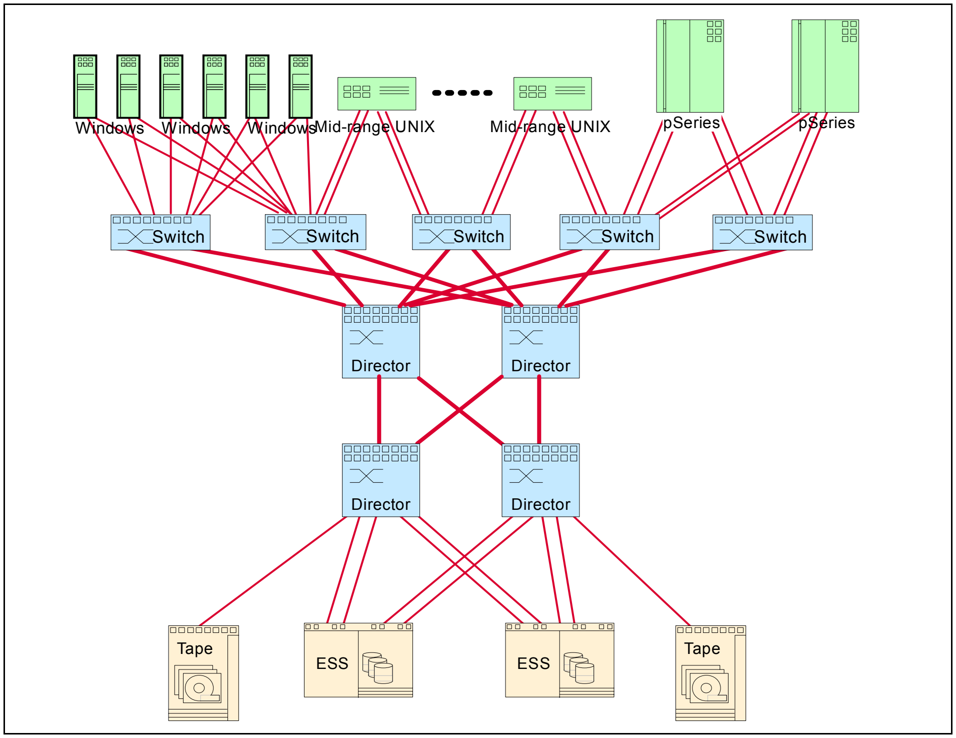


Figure 9-2 M12 core-edge solution

Components

- SAN fabric:
  - Two 64-port and two 32-port (logical) switches 2109-M12 (two chassis)
  - Five 16-port switches 2109-F16
- Servers:
  - Six xSeries servers each configured with dual FC HBAs
  - Eight UNIX servers each configured with four FC HBAs
  - Two pSeries servers each configured with four FC HBAs
- Storage:
  - Two ESS 2105-800 with four native FC Adapter each
  - IBM 3590 Tape Subsystem with native FC Adapter
- Software:
  - IBM Subsystem Device Driver (SDD)

Checklist

- Install and configure switches.
- Install Fibre Channel HBAs.
- Configure ESS.
- Attach ESS to switch.
- Attach servers to switch.
- Validate failover/fail back operations.
- List of firmware/drivers, revisions of servers, HBA, and storage

Performance

Just taking the disk storage into account, the server to storage oversubscription of this design is 6.5:1 (52 / 8). Host-tier and core is connected by 10 ISLs while the storage-tier connects to the core by 4 ISLs. That gives us an ISL oversubscription of 13:1 (52 / 4), and we will check the utilization over a set time frame to decide whether to add more ISLs. Typically an ESS FC adapter will operate at up to 130 MB/s. With the eight connections from the fabric to the storage, we get a maximum SAN peak bandwidth capability of 1040 MB/s (8 x 130 MB/s). This design can support hundreds of end-node connections with high throughput.

Scalability

We connected 52 host ports and eight storage ports to the fabric. The host-tier takes 80 ports of the 2109-F16 and the storage-tier takes 64 ports by using a 32-port 2109-M12. That gives us enough ports to connect 4 trunks (16 ISLs in total) between the core and storage tier, and leaves us spare device ports.

This design is highly scalable, the 2109-M12 provides a very high port density and additional blades can be added. The 2109-F16 may be replaced by the 2109-F32 to increase the port count on the server side.

Availability

This design is appropriate when the server to storage connections need to be highly available; a single switch can fail or be taken off-line for maintenance such as firmware upgrade, and the fabric will still support all the connected devices, although there may be a lack of performance.

The 2109-F16 does not support non-disruptive upgrade, and require the switch to be reinitialized (reboot) for each upgrade. The 2109-M12 at this time needs a CP-failover after the firmware upgrade which is also disruptive.

To provide high availability, connect the four logical switches over the two chassis like that shown in Figure 9-3.

Whenever one chassis fails, there is still one core and one edge switch active.

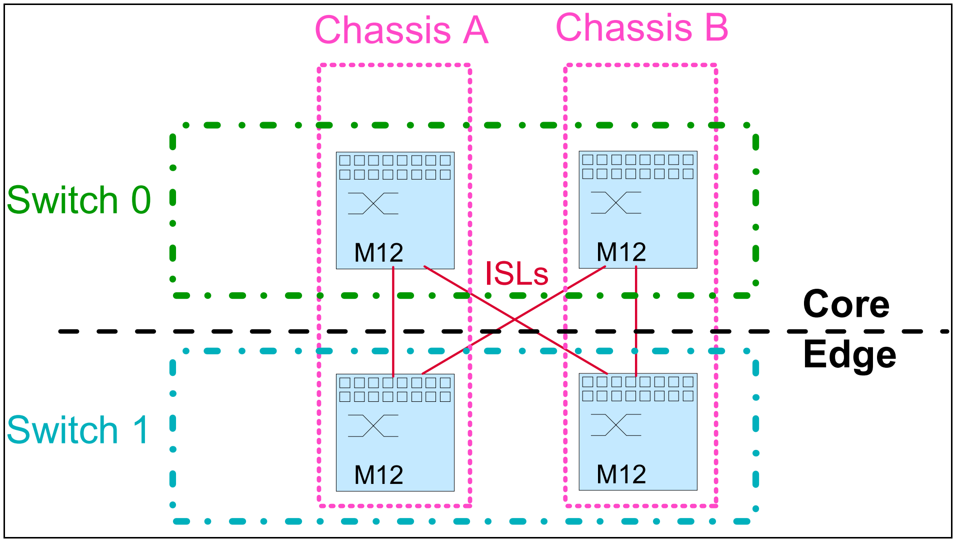


Figure 9-3 2109-M12 placement for availability

Security

The ESS performs LUN masking by default so all devices with LUNs defined have two levels of security; LUN masking and zoning.

If you are unable to identify the causes of a configuration error, you may need to restore from a backup or clear the zoning information on the switch that is being added or merged.

This is why it is important to back up the zoning information periodically, and as and when changes are made. If errors are made in the zoning information, you may restore from the backup.

"What If" failure scenarios

Here we consider the following scenarios:

- **Server HBA:** If one of the HBAs fails, IBM SDD software will automatically failover the workload to the alternate HBA. A Windows server will lose up to 50% of the server SAN bandwidth. An UNIX/AIX server will lose up to 25% of the server SAN bandwidth. Once you have replaced the HBA, you will need to redefine the WWN for the HBA.
- **Cable:** If a cable between a server and the switch fails, IBM SDD software will automatically failover workload to the alternate path. A Windows server will lose up to 50% of the server SAN bandwidth. An UNIX/AIX server will lose up to 25% of the server SAN bandwidth.

- **Cable:** If a cable between the switch and the disk storage fails, the alternate route will be used. The overall SAN performance will degrade by up to 12.5%. On the servers connected to the affected switch, the SAN performance impact will be up to 50% (up to 25% for the UNIX/AIX servers). Servers connected to other storage will not be affected.
- **Cable:** If one of the ISLs breaks, an alternate route will be used based on FSPF. The SAN performance will degrade by up to 25%.
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable SFP.
- **Switch power supply:** Redundant power supplies are already provided by the 2109-M12 and may be added to the 2109-F16. Should one power supply fail, another will take over automatically.
- **Switch:** If a switch at the host-tier fails, the server will use the alternate switch to connect to the disk storage. The overall SAN performance will degrade by up to 20%, and the servers connected to the switch will be affected by up to 50% (up to 25% for the UNIX/AIX servers). Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID.
- **Switch:** If a switch at the storage-tier fails, the server will use the alternate switch to connect to the disk storage. The overall SAN performance will degrade by up to 50%, and the servers using that switch to connect to their storage will be affected by up to 50% and one of the tape drives will not be reachable. Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID.
- **Switch:** If one 2109-M12 chassis fails, we lose one core-switch out of the core-tier and one off the edge. The loss of one core-switch will cause an overall SAN performance degradation by up to 50%, and the servers using that switch to connect to their storage will be affected by up to 50%. The loss of one edge switch will affect all servers connecting to the storage via that switch and will cause a performance loss of up to 50% for each ESS, and one of the tape drives will not be reachable. Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID.
- **Storage:** If one ESS fails, the servers connected will not be able to access the storage. The other ESS may be used to mirror data from the primary ESS, or data has to be restored from a tape subsystem device.

9.2.2 Dual fabric

In Figure 9-4 we show a two-tier highly available enterprise SAN design with redundancy and failover, and a multi-stage switch interconnect to allow for many-to-many connectivity.

Typically, a two-tier design has a host-tier and a storage-tier. All hosts are connected to the host-tier and all storage is connected to the storage-tier. A path from a host to its storage is always just a single hop away.

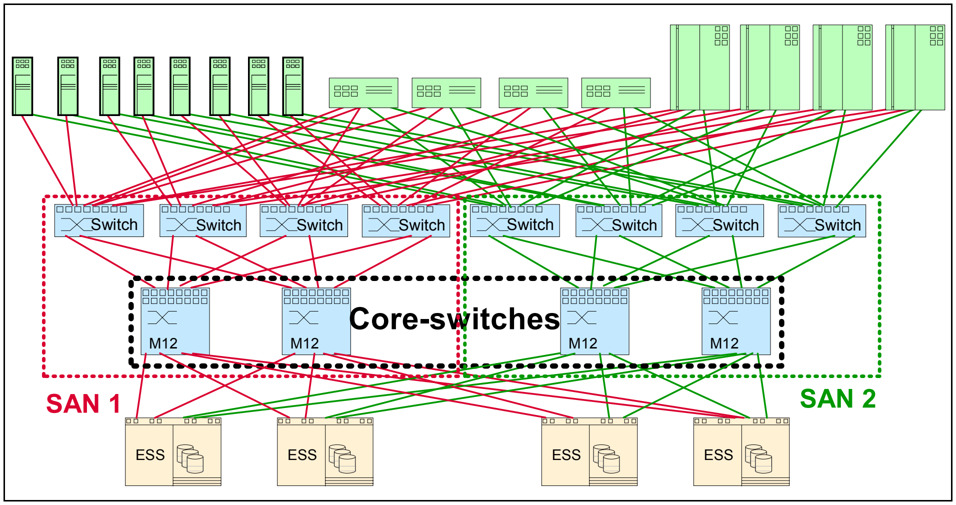


Figure 9-4 High availability dual enterprise SAN fabric

As mentioned earlier, a single SAN is still a single point of failure: it could be affected by a number of events including the following:

- Incorrect zoning change
- Site outages
- Firmware failures
- SAN segmentation

By implementing a solution based on dual fabrics, we can avoid the impact of a SAN fabric failure. Two separate fabrics have been implemented, each one with a 2109-M12 cluster as the storage-tier and multiple 2109-F32s for host connection.

Components

- SAN fabric:
  - Four 64-port (logical) switches 2109-M12 (two chassis)
  - Eight 32-port switches 2109-F32
- Servers:

  - Eight Windows 2000 servers each configured with dual FC HBAs
  - Four UNIX servers each configured with four FC HBAs
  - Four pSeries servers each configured with four FC HBAs
- Storage:
  - Four ESS 2105-800s with four native FC Adapter each
- Software:
  - IBM Subsystem Device Driver (SDD)

Checklist

- Install and configure switches.
- Install Fibre Channel HBAs.
- Configure ESS.
- Attach ESS to switch.
- Attach servers to switch.
- Validate failover/fail back operations.
- List of firmware/drivers, revisions of servers, HBA, and storage

Performance

The server to storage port oversubscription of this design is 3:1 (48 / 16), which is well below the recommended 6:1. The host-tier and storage-tier is connected by 12 ISLs and gives us an oversubscription of 48:12, that is 4:1 and no bottleneck to the end-nodes. Typically an ESS FC adapter will operate at up to 130 MB/s. With the 16 connections from the fabric to the storage, we get a maximum SAN peak bandwidth capability of 2080 MB/s (16 x 130 MB/s). This design can support hundreds of end-node connections with high throughput.

Scalability

A dual SAN fabric is a topology where you have two independent SANs that connect the same hosts and storage devices. All hosts and storage must be connected to both switches to achieve high availability. The high port density of the switches makes the dual fabrics highly scalable.

We connected 48 host ports to the fabric and 16 storage ports. Each tier provides 256 ports. The ISL connections may be implemented as 12 trunks with 4 ISLs each, and leaves us 208 host ports at the host-tier, and up to 208 ports for storage. That would give us an oversubscription of approximately 9:1 (416 / 48).

Availability

This design is appropriate when the fabric itself needs to be highly available; a single switch can fail or be taken off-line for maintenance such as a firmware upgrade, and the fabric will still support all the connected devices (devices do require one redundant entry point to the fabric).

The 2109-F32/F16 and 3534-F08 do not support non-disruptive upgrades, and require the switch to be reinitialized (reboot) for each upgrade. The 2109-M12 (at the time of writing) needs a CP-failover after the firmware upgrade which is also disruptive.

The storage-tier consists of 2109-M12s, which is two logical switches in one chassis. It is not recommended to use these two switches in a redundant fabric or redundant core, as there is still the chassis as a single point of failure shown to the left in Figure 9-5.

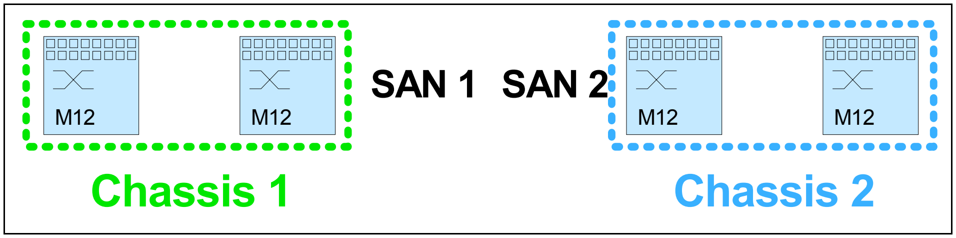


Figure 9-5 2109-M12 deployment

Instead you may want to split the two fabrics, SAN 1 and SAN 2, over the two chassis like that shown in Figure 9-6. Whenever one chassis fails, there is still any-to-any server storage connectivity over both of the fabrics.

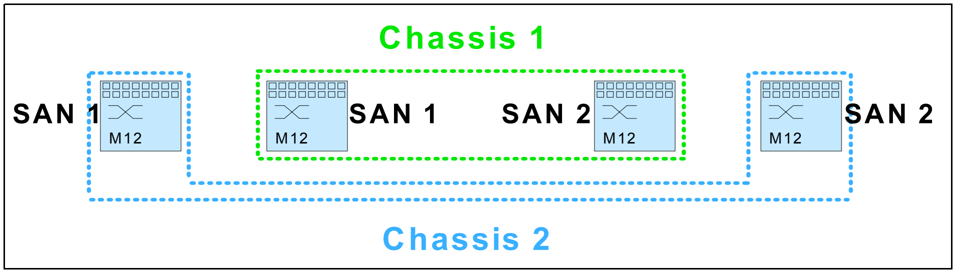


Figure 9-6 2109-M12 high availability deployment

Security

The ESS performs LUN masking by default, so all devices with LUNs defined have two levels of security, LUN masking and zoning. This dual SAN fabric design protects against a fabric wide outage such as inappropriate or accidental changes to zoning information. This zoning would only affect one SAN fabric, so the hosts are able to access their storage through the alternate SAN fabric.

If you are unable to identify the causes of a configuration error, you may need to restore from a backup or clear the zoning information on the switch that is being added or merged.

This is why it is important to back up the zoning information periodically, and as and when changes are made. If errors are made in the zoning information, you may restore from the backup.

“What If” failure scenarios

Here we consider the following scenarios:

- **Server HBA:** If one of the HBAs fails, IBM SDD software will automatically failover the workload to the alternate HBA. Once you have replaced the HBA, you will need to redefine the WWN for the HBA.
- **Cable:** If a cable between a server and the switch fails, IBM SDD software will automatically failover workload to the alternate path.
- **Cable:** If a cable between the switch and the disk storage fails, the alternate route will be used. The overall SAN performance will degrade by up to 6.25%. On the servers connected to the affected switch, the SAN performance impact will be up to 50%. Servers connected to other storage will not be affected.
- **Cable:** If one of the ISLs breaks in one of the SAN fabric, an alternate route will be used based on FSPF. The SAN performance will degrade by up to 8.33%.
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable SFP.
- **Switch power supply:** Redundant power supplies are already provided by the 2109-F32 and 2109-M12, and should one fail, another will take over automatically.
- **Switch:** If a switch at the host-tier fails, the server will use the alternate switch to connect to the disk storage. The overall SAN performance will degrade by up to 12.5%, and the servers connected to the switch will be affected by up to 50%. Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID.
- **Switch:** If a switch at the storage-tier fails, the server will use the alternate switch to connect to the disk storage. The overall SAN performance will degrade by up to 25%, and the servers using that switch to connect to their storage will be affected by up to 25%. Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID.
- **Switch:** If one 2109-M12 chassis fails, we lose one core-switch in each fabric. The overall SAN performance will degrade by up to 50%, and the servers using that switch to connect to their storage will be affected by up to 50%.

Once the switch is replaced, all zoning information will be automatically propagated from the other switch via an ISL, as long as there is no previous zoning information, or there have been any changes to either the zoning or the domain ID

- **Storage:** If one ESS fails, the servers connected will not be able to access the storage. One ESS may be used to mirror data from the primary ESS, or data has to be restore from a tape subsystem device.

9.3 Distance solutions

In the following topics we focus on distance solutions.

9.3.1 Extended Fabric feature

In Figure 9-7 we show a basic mirroring and disaster tolerance solution accomplished by protecting primary data using a remote mirror and “hot stand-by” disaster recovery site. When the primary site fails, a remote system takes over (imports) the storage volumes. The services can be manually started on the remote system and have access to the mirrored data.

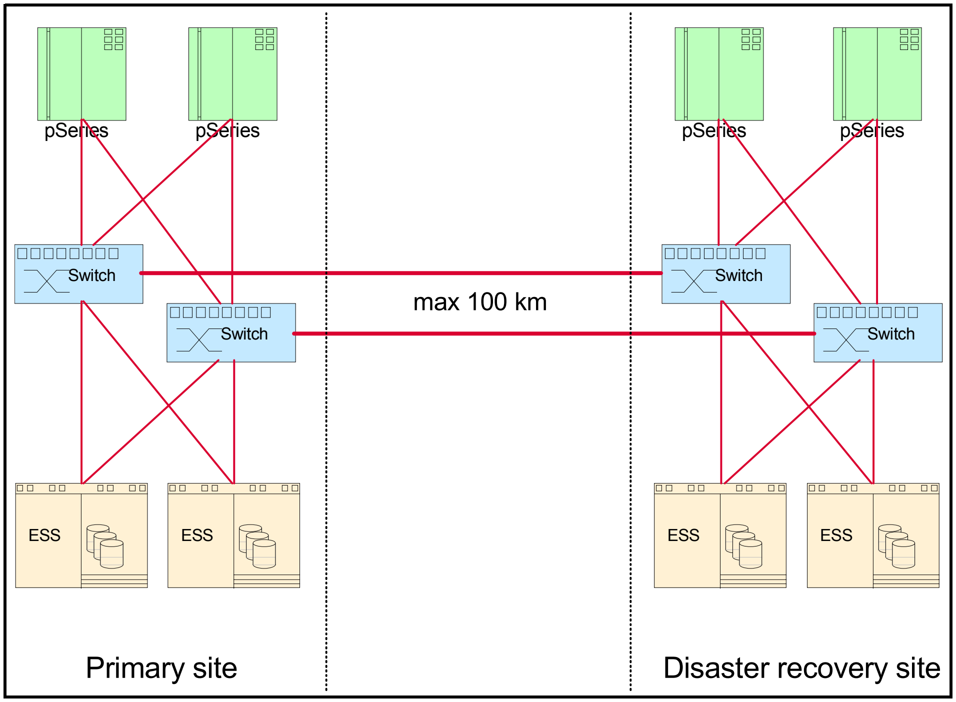


Figure 9-7 Two-switch fabric for mirroring and disaster tolerance

There are two high performance servers connected to the switches with a redundant fabric to access the two storage devices, with redundant connections at each location.

The Extended Fabric feature (for more information see “Extended Fabric” on page 206) provides extensions within the internal switch buffers to maintain performance with distances greater than 10 km and up to 120 km. As this is a highly available solution, an alternate redundant path is connected from the primary site to the disaster recovery site.

Veritas Volume Manager is used to mirror the content from disk storage in the primary location to the disaster recovery location. If the primary site fails, the disaster recovery site will be activated.

Components

- SAN fabric:
  - Four 16-port IBM SAN Fibre Channel Switch Model 2109-F16
- Servers:
  - Four IBM pSeries servers each configured with dual FC HBAs

- Storage:
  - Four ESS 2105-800 with two native FC Adapters
- Software:
  - Veritas Volume Manager
  - IBM Subsystem Device Driver (SDD)
  - 2109 Extended Fabric feature

Checklist

- Install and configure switches.
- Activate 2109 Extended Fabric feature.
- Install Fibre Channel Host Bus adapters.
- Configure ESS.
- Attach ESS to switch.
- Install Veritas Volume Manager software.
- Attach servers to switch.
- Validate failover/failback operations.
- List of firmware/drivers, revisions of servers, HBA, and storage.

Performance

The above configuration is based on a 1:1 server to storage oversubscription and is clearly within our predefined 6:1 ratio. Typically an ESS FC adapter will operate at up to 130 MB/s. The four connections from the fabric to the storage give us a maximum SAN peak bandwidth capability of 520 MB/s (4 x 130 MB/s).

Scalability

Based on maintaining our 6:1 ratio, this design is able to accommodate up to 12 high performance servers with a redundant fabric, and two storage devices with a redundant fabric on two F16s in each location. This is 24 servers and four storage devices in total. The total number of ISLs to interconnect the primary site to the disaster recovery site can be increased to two trunks with four ISLs each. By adding more switches or implementing 2109-F32 switches, it can scale much higher.

Availability

This design is appropriate when the fabric itself needs to be highly available; a single switch can fail or be taken off-line for maintenance such as a firmware upgrade, and the fabric will still support all connected devices (devices do require one redundant entry point to the fabric).

The 2109-F16/F32 and 3534-F08 do not support a non-disruptive upgrade, and require the switch to be reinitialized (reboot) for each upgrade.

Security

The primary site may be shielded from the disaster recovery site using zoning. The disaster recovery site is used to mirror data from the primary site, and have access to the primary site, however, users from the primary site will not be able to access the disaster recovery site. In the event that the primary site's storage fails, zoning information from the disaster recovery site may be propagated to the primary site to allow access to the disaster recovery site's storage.

However, should the entire primary site fail, it will be necessary to declare a disaster and shift to the disaster recovery site.

"What If" failure scenarios

Here we consider the following scenarios:

- **Server:** If one of the servers fails, users connected to that server will not be able to gain access to the ESS. The overall SAN performance in a site will be degraded by 50%.
- **Server HBA:** If one of the HBAs fails, IBM SDD software will automatically failover the workload to the alternate HBA. The server will lose up to 50% of the SAN bandwidth. Once you have replaced the HBA, you will need to redefine the WWN for the HBA.
- **Cable:** If a cable between a server and the switch fails, IBM SDD software will automatically failover workload to the alternate path. The SAN performance will be degraded by p to 50%.
- **Cable:** If a cable between the switch and the storage fails, the alternate route will be used. The SAN performance to that storage will be degraded by up to 50%. The overall SAN performance may degrade by up to 25%.
- **Cable:** If a cable between the switch in the primary and secondary site fails, the alternate route will be used. The overall mirroring SAN performance will be degraded by up to 50% (up to 12.5%, when eight ISLs are in use).
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable SFP.
- **Switch power supply:** Another redundant power supply may be added to the switch, and should one fail, the other will take over automatically.
- **Switch:** If a switch fails, the server will use the alternate switch to connect to the storage. The overall SAN performance in a site will be degraded by up to 50%. Once the switch is replaced, all zoning information will be automatically propagated from the other switch.
- **Storage:** If the ESS fails, the SAN will failover to the disaster recovery site to access the redundant ESS.

- **Site**: If the primary site fails, the disaster recovery site may be activated by shifting the operation to the disaster recovery site.

9.3.2 Remote Switch

This feature enables two switches to interconnect over a WAN by gateways, as shown in Figure 9-8. The gateway supports both Fibre Channel Physical Interface as well as a secondary interface like ATM (for more information, see “Remote Switch” on page 214).

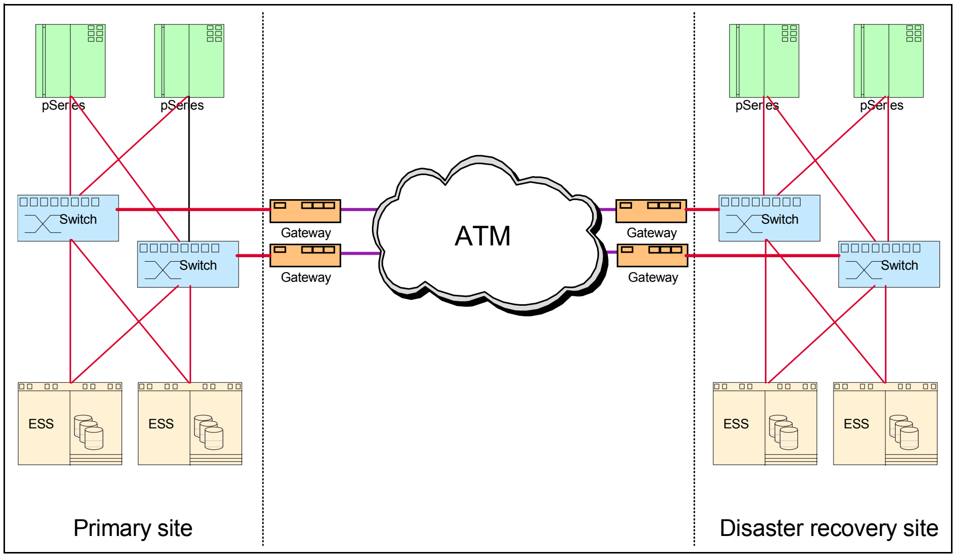


Figure 9-8 Disaster tolerance using ATM

Components

- SAN fabric:
  – Four 16-port 2109-F16s
- Servers:
  – Four IBM pSeries servers each configured with dual FC HBAs
- Storage:
  – Four ESS 2105-800 with two native FC Adapter
- ATM access with four CNT ATM Gateways
- Software:
  – Veritas Volume Manager
  – IBM Subsystem Device Driver (SDD)
  – 2109 Remote Switch feature

If we look at “Extended Fabric feature” on page 288, the details for Checklist, Performance, Scalability, Availability, Security, and “What If” failure scenarios remain the same.

9.4 Clustering solutions

These topics focus on clustering solutions.

9.4.1 Two-node clustering

In Figure 9-9 we show a typical basic high availability SAN design for a two-node clustering and redundant fabric. This design is typically for a small fabric with two to four hosts using Microsoft NT 4.0/EE servers.

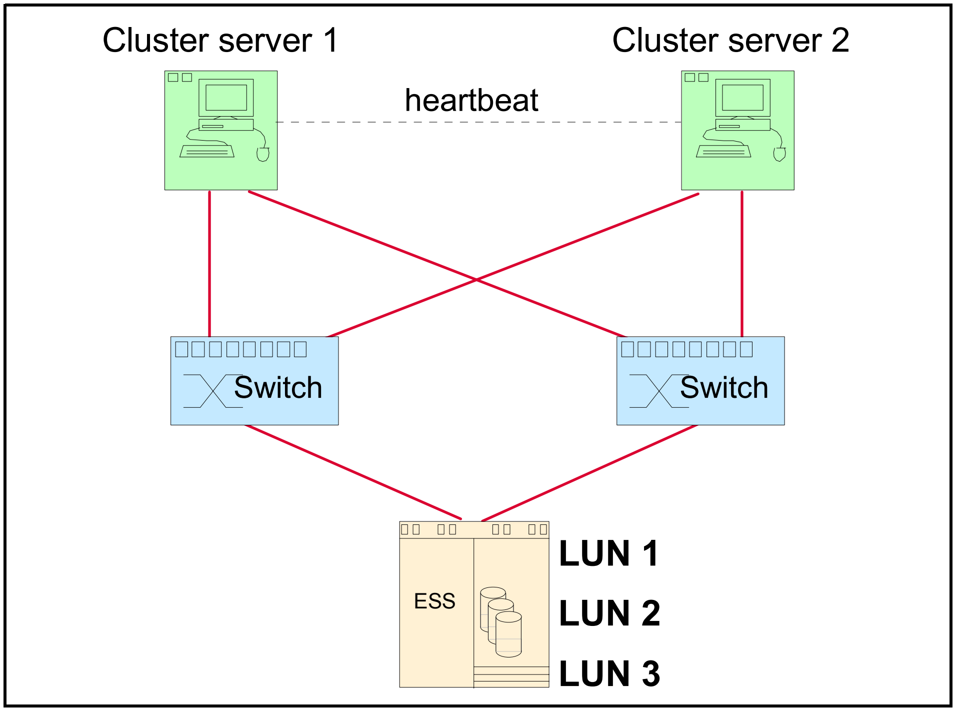


Figure 9-9 Microsoft cluster with dual switch with redundant fabric

Components

- SAN fabric:
  - Two 16-port IBM SAN Fibre Channel Switch Model 2109-F16
- Servers:
  - Two IBM xSeries servers each configured with dual FC HBAs
- Storage:
  - One ESS 2105-F20 with two native FC Adapters,
- Software:
  - IBM Subsystem Device Driver (SDD)

Checklist

- Install and configure switches.
- Install Fibre Channel HBAs.
- Configure ESS.
- Attach ESS to switch.
- Install Veritas Volume Manager software.
- Attach servers to switch.
- Validate failover/failback operations.
- List of firmware/drivers, revisions of servers, HBA, and storage.

Performance

Typically, for a low performance server, the recommended server to storage oversubscription is 12:1, and for a high performance server, the server to storage oversubscription is 6:1. With a 2:1 ratio (4 / 2), the above configuration is within ratio provided based on four server connections to two storage connections.

To increase the performance of the SAN, multiple connections may be added from the hosts to the switches and from the switches to the storage devices.

Scalability

A dual SAN fabric is a topology where you have two independent SANs that connect the same hosts and storage devices. This design is not one of the most highly scalable as all hosts and storage must be connected to both switches to achieve high availability.

Two 2109-F16s give enough spare ports to build a larger fabric which will be illustrated in Figure 9-10, “Datacenter Server 2000 for MSCS” on page 296.

Availability

In addition to the server high availability clustering, SAN high availability is provided with this dual switch, dual fabric design. Dual HBAs are installed in each host and the storage device must have at least two ports. Fail over for a failed path or even a failed switch is dependent on host failover software, namely, the IBM Subsystem Device Driver (SDD). The switches do not reroute traffic for a failed link as there is no fabric or meshed network with this type of design. Each switch is a single-switch fabric.

Security

The ESS performs LUN masking by default so all devices with LUNs defined have two levels of security, LUN masking and zoning.

This dual SAN fabric design protects against a fabric wide outage such as inappropriate or accidental change to zoning information. This zoning would only affect one single SAN fabric, so the hosts could still be able to access their storage through the alternate SAN fabric.

If you are unable to identify the causes of a configuration error you may need to restore from a backup or clear the zoning information on the switch that is being added or merged.

Should you decide to add an ISL to change this design into a meshed design, ensure proper zoning guidelines are followed.

“What If” failure scenarios

Here we consider the following scenarios:

- **Server:** The clustering solution will failover to the passive server dynamically.
- **Server HBA:** If one of the HBAs fails, IBM SDD software will automatically failover the workload to the alternate HBA. The active server of the cluster will lose up to 50% bandwidth.
- **Cable:** If a cable between a server and the switch fails, IBM SDD software will automatically failover workload to the alternate path.The active server will lose up to 50% bandwidth.
- **Cable:** If a cable between the switch and the disk storage fails, an alternate route will be used. The active server will lose up to 50% bandwidth.
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable SFP.
- **Switch power supply:** Another redundant power supply may be added to the switch, and should one fail, the other will take over automatically.
- **Switch:** If a switch fails, the server will use the alternate switch to connect to the storage. The active server will lose up to 50% bandwidth. Once the switch is replaced, all zoning information will be automatically propagated from the other switch.

- **Storage:** If the ESS fails, the servers will not be able to access the storage. A redundant ESS may be added to mirror data from the primary ESS.

9.4.2 Multi-node clustering

In Figure 9-10 we extend the environment in Figure 9-7 on page 289. It is extended to increase the number of nodes to up to eight nodes in a single cluster using Datacenter Server 2000 for Microsoft Cluster Server.

Microsoft 2000 clustering: The Windows Server 2003 family supports server clusters for up to eight nodes. Refer to `http://www.microsoft.com` for more details.

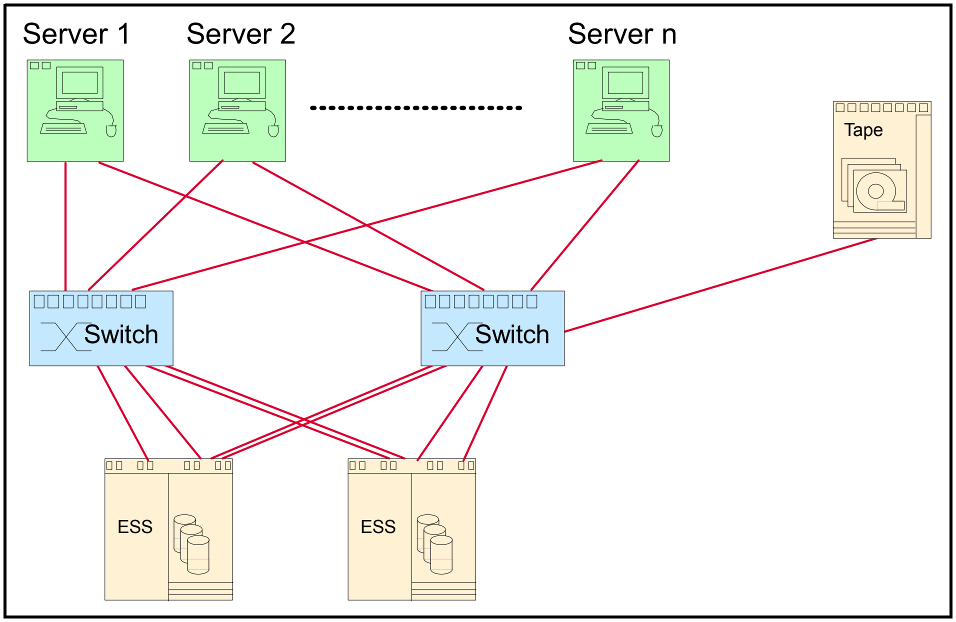


Figure 9-10 Datacenter Server 2000 for MSCS

In Figure 9-10, we show a high availability SAN design for an eight-node cluster using the Datacenter Server 2000 for Microsoft Cluster Server connected to two F16 switches with redundant fabric, which allows access to the two ESSs.

Apart from server failover, this design provides failover for HBAs and switches. Dual HBAs are installed in each host and each storage device must have at least two ports. Fail over for a failed path or even a failed switch is dependent on the host failover software, namely the IBM Subsystem Device Driver (SDD).

Components

- SAN fabric:
  - Two 2109-F16s
- Servers:
  - Eight IBM xSeries servers each configured with dual FC HBAs
- Storage:
  - Two ESS 2105-F20 with native FC adapters
  - IBM 3590 Tape Subsystem with native FC Adapter
- Software:
  - IBM Subsystem Device Driver (SDD)

Checklist

- Install and configure switches.
- Install Fibre Channel HBAs.
- Install and certify Datacenter Server 2000.
- Install IBM Tivoli Storage Manager.
- Configure tape subsystem.
- Configure ESS.
- Attach storage to switch.
- Install Veritas Volume Manager software.
- Attach servers to switch.
- Validate failover/failback operations.
- List of firmware/drivers, revisions of servers, HBA, and storage.

Performance

This solution is configured based on the ratio of eight servers to two storage devices with a redundant fabric. Hence, the effective oversubscription will be 4:1 and is within our predefined 6:1 ratio. To increase the performance of the SAN more ESS ports may be connected to the switches.

Scalability

A dual SAN fabric is a topology where you have two independent SANs that connect the same hosts and storage devices. This design is not the highest scalable as all hosts and storage must be connected to both switches to achieve high availability.

This design accommodates eight hosts and two storage devices with redundancy with two F16s. The additional ports may be used to connect to other storage devices.

Availability

In addition to the server high availability clustering, SAN high availability is provided with this dual switch, dual fabric design. Dual HBAs are installed in each host and the storage device must have at least two ports. Fail over for a failed path or even a failed switch is dependent on host failover software, namely, the IBM Subsystem Device Driver (SDD). The switches do not reroute traffic for a failed link as there is no fabric or meshed network with this type of design. Each switch is a single-switch fabric.

Security

The ESS performs LUN masking by default so all devices with LUNs defined have two levels of security, LUN masking and zoning.

This dual SAN fabric design protects against a fabric wide outage such as inappropriate or accidental changes to zoning information. This zoning would only affect one single SAN fabric, so the hosts could still access their storage through the alternate SAN fabric.

If you are unable to identify the causes of a configuration error, you may need to restore from a backup or clear the zoning information on the switch that is being added or merged.

Should you decide to add an ISL to change into a meshed design, ensure proper zoning guidelines are followed.

“What If” failure scenarios

Here we consider the following scenarios:

- **Server:** The clustering solution will failover to the passive server dynamically.
- **Server HBA:** If one of the HBAs fails, IBM SDD software will automatically failover the workload to the alternate HBA. The active server of the cluster will lose up to 50% bandwidth.
- **Cable:** If a cable between a server and the switch fails, IBM SDD software will automatically failover workload to the alternate path.The active server will lose up to 50% bandwidth.
- **Cable:** If a cable between the switch and the disk storage fails, an alternate route will be used. The active server will lose up to 50% bandwidth.
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable SFP.
- **Switch power supply:** Another redundant power supply may be added to the switch, and should one fail, the other will take over automatically.

- **Switch:** If a switch fails, the server will use the alternate switch to connect to the storage. The active server will lose up to 50% bandwidth. Once the switch is replaced, all zoning information will be automatically propagated from the other switch.
- **Storage:** If one ESS fails, the servers will not be able to access that storage. The other ESS may be used to mirror data from the primary ESS.

9.5 Secure solutions

The following example uses our previous solution “Single fabric” on page 279 and implemented here as a secure solution.

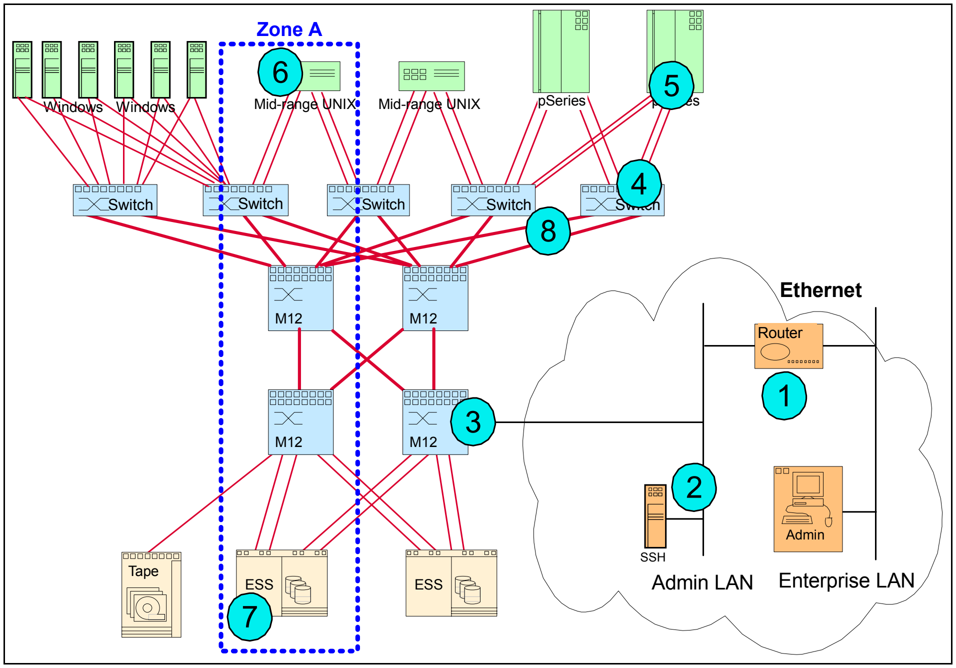


Figure 9-11 Secure SAN

Checklist

- Install and configure switches with Secure Fabric OS.
- Install SSH server and firewall.
- Validate security functions.
- List of firmware/drivers, revisions of servers, HBA, and storage.

“What If” violation scenarios

Here we consider the following scenarios:

- **Ethernet:** If unauthorized IP sessions are attempted to be established, firewall (1) will protect the admin LAN. SAN administrator will connect from the enterprise LAN to the admin LAN to the SSH server (2). SSH fully encrypts the data stream, including passwords, between the source and destination, so it cannot be read with a LAN sniffing tool. Once connected to this system, the administrator can access the 2109-M12 (3). DOS attacks and broadcast storms in the enterprise SAN are blocked on the firewall boundary. Refer to 6.5.2, “Management access controls” on page 203 for further information on this.
- **Configuration changes:** If any change is to made, the 2109-M12 (3), as a *trusted switch*, acts as the Fabric Configuration Server and is responsible for managing the zoning configuration and security settings of all other switches in the fabric. Refer to 6.5.1, “Fabric configuration servers” on page 203 for further information on this.
- **Device connection:** With Access Control Lists (ACLs) individual device ports can be bound to a set of one or more switch ports (4). Any device not specified in the ACL will not be able to log into the fabric (5). Refer to 6.5.3, “Device connection controls” on page 204 for further information on this.
- **Data traffic:** Any FC device (6) trying to attach to another device (7) in Zone A will be checked by hardware. If not authorized, access will be denied. Refer to 6.9.4, “Zoning types” on page 219 for further information.
- **Switch connection:** When a new switch is connected to a switch that is already part of the fabric (8), both switches must be authenticated. This makes sure that only authorized switches may form a fabric. Refer to 6.5.4, “Switch connection controls” on page 204 for further information. Another way to limit the connection of a new switch is to limit the function of a port to become an E_Port.

The details for components, performance, scalability and availability remain the same as in 9.2.1, “Single fabric” on page 279.

9.6 Loop solutions

QuickLoop is used to connect a non-fabric aware host in a SAN. In Figure 9-12, we configured three ports on the switch with QuickLoop to support FC-AL (for further details see “QuickLoop” on page 206). In this case a tape drive attached to the switch is configured as an FC-AL device, and Server 1 and Server 2 only support private loop. Server 3 is a fabric FC device.

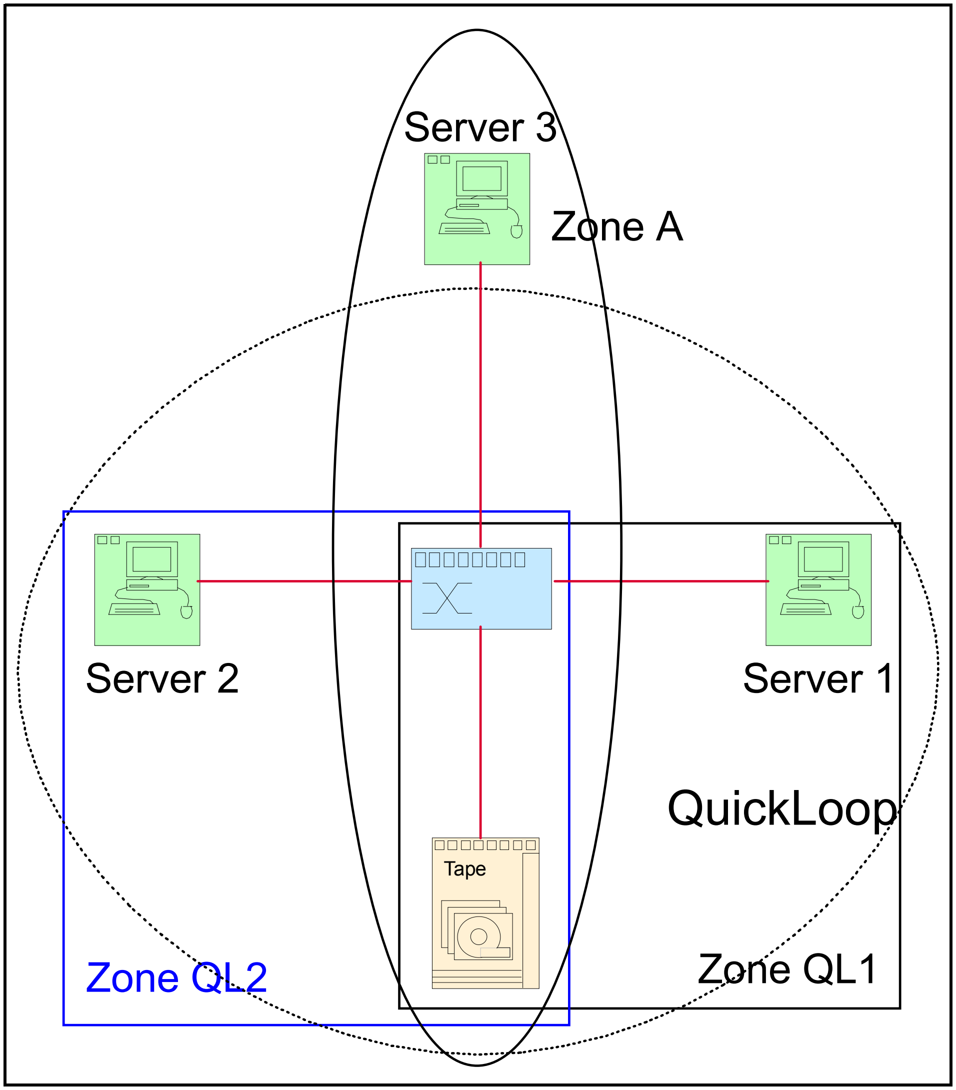


Figure 9-12 QuickLoop

The private hosts (Server 1 and Server 2) may connect to the private tape drive. The public host (Server 3) may communicate with the tape drive too using translative mode.

Components

- IBM 3534-F08
- Servers:
  - Three HP UNIX servers each configured with one FC HBA
- Storage:
  - IBM 3590 Tape Subsystem with native FC adapter

Checklist

- Install and configure switch.
- Install Fibre Channel HBAs.
- Configure IBM 3590 Tape Subsystem.
- Attach storage to switch.
- Attach servers to switch.
- List of firmware/drivers, revisions of servers, HBA, and storage.

Performance

QuickLoop supports a 100 MB/s transfer rate shared throughout all devices within the loop. As more devices are added, the performance will decrease.

Scalability

You may have up to 126 devices (127 including the initiator) in a FC-AL loop. QuickLoop cannot span over more than two switches, and the 3534-F08 has eight ports only.

Availability

It is not a high availability solution as a failure of the fabric will stop any server to storage connectivity. A possible fabric failure could be an invalid zoning change, a corrupted configuration, a switch reboot, or similar outage.

Security

By establishing zones in a QuickLoop, you may isolate certain devices from being disrupted from LIPs in the QuickLoop.

If a server in Zone QL1 fails, LIP will take place and will affect the storage, but not the server in Zone QL2, and vice versa.

“What If” failure scenarios

Here we consider the following scenarios:

- **Server HBA:** If one of the HBAs fails, the server will lose its storage access. Once you have replaced the HBA, you will need to redefine the WWN for the HBA.
- **Cable:** If a cable between a server and the switch fails, the server will lose its storage access.
- **Cable:** If a cable between the switch and the tape drive fails, each server will lose access to the drive.
- **Switch port:** If one of the ports fails, you may replace it using a hot-pluggable GBIC.
- **Switch power supply:** Another redundant power supply may be added to the switch, and should one fail, the other will take over automatically.
- **Switch:** If the switch fails, each server will lose access to the drive. It is important to back up the zoning information periodically, and as and when changes are made. If the faulty switch is replaced you may restore information from the backup.
- **Storage:** If the tape drive fails, each server will lose access to it.

Glossary

8b/10b A data encoding scheme developed by IBM, translating byte-wide data to an encoded 10-bit format. Fibre Channel's FC-1 level defines this as the method to be used to encode and decode data transmissions over the Fibre Channel.

Adapter A hardware unit that aggregates other I/O units, devices or communications links to a system bus.

ADSM ADSTAR Distributed Storage Manager.

Agent (1) In the client-server model, the part of the system that performs information preparation and exchange on behalf of a client or server application. (2) In SNMP, the word agent refers to the managed system. See also: Management Agent

Aggregation In the Storage Networking Industry Association Storage Model (SNIA), *virtualization* is known as *aggregation*. This aggregation can take place at the file level or at the level of individual blocks that are transferred to disk.

AIT Advanced Intelligent Tape - A magnetic tape format by Sony that uses 8mm cassettes, but is only used in specific drives.

AL See Arbitrated Loop

AL_PA Arbitrated Loop Physical Address

ANSI American National Standards Institute - The primary organization for fostering the development of technology standards in the United States. The ANSI family of Fibre Channel documents provide the standards basis for the Fibre Channel architecture and technology. See FC-PH

Arbitration The process of selecting one respondent from a collection of several candidates that request service concurrently.

Arbitrated Loop A Fibre Channel interconnection technology that allows up to 126 participating node ports and one participating fabric port to communicate.

ATL Automated Tape Library - Large scale tape storage system, which uses multiple tape drives and mechanisms to address 50 or more cassettes.

ATM Asynchronous Transfer Mode - A type of packet switching that transmits fixed-length units of data.

Backup A copy of computer data that is used to recreate data that has been lost, mislaid, corrupted, or erased. The act of creating a copy of computer data that can be used to recreate data that has been lost, mislaid, corrupted or erased.

Bandwidth Measure of the information capacity of a transmission channel.

Bridge (1) A component used to attach more than one I/O unit to a port. (2) A data communications device that connects two or more networks and forwards packets between them. The bridge may use similar or dissimilar media and signaling systems. It operates at the data link level of the OSI model. Bridges read and filter data packets and frames.

Bridge/Router A device that can provide the functions of a bridge, router or both concurrently. A bridge/router can route one or more protocols, such as TCP/IP, and bridge all other traffic. See also: Bridge, Router

Broadcast Sending a transmission to all N_Ports on a fabric.

Channel A point-to-point link, the main task of which is to transport data from one point to another.

Channel I/O A form of I/O where request and response correlation is maintained through some form of source, destination and request identification.

CIFS Common Internet File System

Class of Service A Fibre Channel frame delivery scheme exhibiting a specified set of delivery characteristics and attributes.

Class-1 A class of service providing dedicated connection between two ports with confirmed delivery or notification of non-deliverability.

Class-2 A class of service providing a frame switching service between two ports with confirmed delivery or notification of non-deliverability.

Class-3 A class of service providing frame switching datagram service between two ports or a multicast service between a multicast originator and one or more multicast recipients.

Class-4 A class of service providing a fractional bandwidth virtual circuit between two ports with confirmed delivery or notification of non-deliverability.

Class-6 A class of service providing a multicast connection between a multicast originator and one or more multicast recipients with confirmed delivery or notification of non-deliverability.

Client A software program used to contact and obtain data from a *server* software program on another computer -- often across a great distance. Each *client* program is designed to work specifically with one or more kinds of server programs and each server requires a specific kind of client program.

Client/Server The relationship between machines in a communications network. The client is the requesting machine, the server the supplying machine. Also used to describe the information management relationship between software components in a processing system.

Cluster A type of parallel or distributed system that consists of a collection of interconnected whole computers and is used as a single, unified **computing resource**.

Coaxial Cable A transmission media (cable) used for high speed transmission. It is called *coaxial* because it includes one physical channel that carries the signal surrounded (after a layer of insulation) by another concentric physical channel, both of which run along the same axis. The inner channel carries the signal and the outer channel serves as a ground.

Controller A component that attaches to the system topology through a channel semantic protocol that includes some form of request/response identification.

CRC Cyclic Redundancy Check - An error-correcting code used in Fibre Channel.

DASD Direct Access Storage Device - any on-line storage device: a disc, drive or CD-ROM.

DAT Digital Audio Tape - A tape media technology designed for very high quality audio recording and data backup. DAT cartridges look like audio cassettes and are often used in mechanical auto-loaders. typically, a DAT cartridge provides 2GB of storage. But new DAT systems have much larger capacities.

Data Sharing A SAN solution in which files on a storage device are shared between multiple hosts.

Datagram Refers to the Class 3 Fibre Channel Service that allows data to be sent rapidly to multiple devices attached to the fabric, with no confirmation of delivery.

dB Decibel - a ratio measurement distinguishing the percentage of signal attenuation between the input and output power. Attenuation (loss) is expressed as dB/km

Disk Mirroring A fault-tolerant technique that writes data simultaneously to two hard disks using the same hard disk controller.

Disk Pooling A SAN solution in which disk storage resources are pooled across multiple hosts rather than be dedicated to a specific host.

DLT Digital Linear Tape - A magnetic tape technology originally developed by Digital Equipment Corporation (DEC) and now sold by Quantum. DLT cartridges provide storage capacities from 10 to 35GB.

E_Port Expansion Port - a port on a switch used to link multiple switches together into a Fibre Channel switch fabric.

ECL Emitter Coupled Logic - The type of transmitter used to drive copper media such as Twinax, Shielded Twisted Pair, or Coax.

Enterprise Network A geographically dispersed network under the auspices of one organization.

Entity In general, a real or existing thing from the Latin ens, or being, which makes the distinction between a thing's existence and it qualities. In programming, engineering and probably many other contexts, the word is used to identify units, whether concrete things or abstract ideas, that have no ready name or label.

ESCON Enterprise System Connection

Exchange A group of sequences which share a unique identifier. All sequences within a given exchange use the same protocol. Frames from multiple sequences can be multiplexed to prevent a single exchange from consuming all the bandwidth. See also: Sequence

F_Node Fabric Node - a fabric attached node.

F_Port Fabric Port - a port used to attach a Node Port (N_Port) to a switch fabric.

Fabric Fibre Channel employs a fabric to connect devices. A fabric can be as simple as a single cable connecting two devices. The term is most often used to describe a more complex network utilizing hubs, switches and gateways.

Fabric Login Fabric Login (FLOGI) is used by an N_Port to determine if a fabric is present and, if so, to initiate a session with the fabric by exchanging service parameters with the fabric. Fabric Login is performed by an N_Port following link initialization and before communication with other N_Ports is attempted.

FC Fibre Channel

FC-0 Lowest level of the Fibre Channel Physical standard, covering the physical characteristics of the interface and media

FC-1 Middle level of the Fibre Channel Physical standard, defining the 8b/10b encoding/decoding and transmission protocol.

FC-2 Highest level of the Fibre Channel Physical standard, defining the rules for signaling protocol and describing transfer of frame, sequence and exchanges.

FC-3 The hierarchical level in the Fibre Channel standard that provides common services such as striping definition.

FC-4 The hierarchical level in the Fibre Channel standard that specifies the mapping of upper-layer protocols to levels below.

FCA Fibre Channel Association.

FC-AL Fibre Channel Arbitrated Loop - A reference to the Fibre Channel Arbitrated Loop standard, a shared gigabit media for up to 127 nodes, one of which may be attached to a switch fabric. See also: Arbitrated Loop.

FC-CT Fibre Channel common transport protocol

FC-FG Fibre Channel Fabric Generic - A reference to the document (ANSI X3.289-1996) which defines the concepts, behavior and characteristics of the Fibre Channel Fabric along with suggested partitioning of the 24-bit address space to facilitate the routing of frames.

FC-FP Fibre Channel HIPPI Framing Protocol - A reference to the document (ANSI X3.254-1994) defining how the HIPPI framing protocol is transported via the Fibre Channel

FC-GS Fibre Channel Generic Services -A reference to the document (ANSI X3.289-1996) describing a common transport protocol used to communicate with the server functions, a full X500 based directory service, mapping of the Simple Network Management Protocol (SNMP) directly to the Fibre Channel, a time server and an alias server.

FC-LE Fibre Channel Link Encapsulation - A reference to the document (ANSI X3.287-1996) which defines how IEEE 802.2 Logical Link Control (LLC) information is transported via the Fibre Channel.

FC-PH A reference to the Fibre Channel Physical and Signaling standard ANSI X3.230, containing the definition of the three lower levels (FC-0, FC-1, and FC-2) of the Fibre Channel.

FC-PLDA Fibre Channel Private Loop Direct Attach - See PLDA.

FC-SB Fibre Channel Single Byte Command Code Set - A reference to the document (ANSI X.271-1996) which defines how the ESCON command set protocol is transported using the Fibre Channel.

FC-SW Fibre Channel Switch Fabric - A reference to the ANSI standard under development that further defines the fabric behavior described in FC-FG and defines the communications between different fabric elements required for those elements to coordinate their operations and management address assignment.

FC Storage Director See SAN Storage Director

FCA Fibre Channel Association - a Fibre Channel industry association that works to promote awareness and understanding of the Fibre Channel technology and its application and provides a means for implementers to support the standards committee activities.

FCLC Fibre Channel Loop Association - an independent working group of the Fibre Channel Association focused on the marketing aspects of the Fibre Channel Loop technology.

FCP Fibre Channel Protocol - the mapping of SCSI-3 operations to Fibre Channel.

Fiber Optic Refers to the medium and the technology associated with the transmission of information along a glass or plastic wire or fiber.

Fibre Channel A technology for transmitting data between computer devices at a data rate of up to 4 Gb/s. It is especially suited for connecting computer servers to shared storage devices and for interconnecting storage controllers and drives.

FICON Fibre Connection - A next-generation I/O solution for IBM S/390 parallel enterprise server.

FL_Port Fabric Loop Port - the access point of the fabric for physically connecting the user's Node Loop Port (NL_Port).

FLOGI See Fabric Log In

Frame A linear set of transmitted bits that define the basic transport unit. The frame is the most basic element of a message in Fibre Channel communications, consisting of a 24-byte header and zero to 2112 bytes of data. See also: Sequence

FSP Fibre Channel Service Protocol - The common FC-4 level protocol for all services, transparent to the fabric type or topology.

FSPF Fabric Shortest Path First - is an intelligent path selection and routing standard and is part of the Fibre Channel Protocol.

Full-Duplex A mode of communications allowing simultaneous transmission and reception of frames.

G_Port Generic Port - a generic switch port that is either a Fabric Port (F_Port) or an Expansion Port (E_Port). The function is automatically determined during login.

Gateway A node on a network that interconnects two otherwise incompatible networks.

Gb/s Gigabits per second. Also sometimes referred to as Gbps. In computing terms it is approximately 1,000,000,000 bits per second. Most precisely it is 1,073,741,824 (1024 x 1024 x 1024) bits per second.

GB/s Gigabytes per second. Also sometimes referred to as GBps. In computing terms it is approximately 1,000,000,000 bytes per second. Most precisely it is 1,073,741,824 (1024 x 1024 x 1024) bytes per second.

GBIC GigaBit Interface Converter - Industry standard transceivers for connection of Fibre Channel nodes to arbitrated loop hubs and fabric switches.

Gigabit One billion bits, or one thousand megabits.

GLM Gigabit Link Module - a generic Fibre Channel transceiver unit that integrates the key functions necessary for installation of a Fibre Channel media interface on most systems.

Half-Duplex A mode of communications allowing either transmission or reception of frames at any point in time, but not both (other than link control frames which are always permitted).

Hardware The mechanical, magnetic and electronic components of a system, for example, computers, telephone switches, terminals and the like.

HBA Host Bus Adapter

HIPPI High Performance Parallel Interface - An ANSI standard defining a channel that transfers data between CPUs and from a CPU to disk arrays and other peripherals.

HMMP HyperMedia Management Protocol

HMMS HyperMedia Management Schema - the definition of an implementation-independent, extensible, common data description/schema allowing data from a variety of sources to be described and accessed in real time regardless of the source of the data. See also: WEBM, HMMP

hop A FC frame may travel from a switch to a director, a switch to a switch, or director to a director which, in this case, is one hop.

HSM Hierarchical Storage Management - A software and hardware system that moves files from disk to slower, less expensive storage media based on rules and observation of file activity. Modern HSM systems move files from magnetic disk to optical disk to magnetic tape.

HUB A Fibre Channel device that connects nodes into a logical loop by using a physical star topology. Hubs will automatically recognize an active node and insert the node into the loop. A node that fails or is powered off is automatically removed from the loop.

HUB Topology see Loop Topology

Hunt Group A set of associated Node Ports (N_Ports) attached to a single node, assigned a special identifier that allows any frames containing this identifier to be routed to any available Node Port (N_Port) in the set.

In-band Signaling This is signaling that is carried in the same channel as the information. Also referred to as in-band.

In-band virtualization An implementation in which the virtualization process takes place in the data path between servers and disk systems. The virtualization can be implemented as software running on servers or in dedicated engines.

Information Unit A unit of information defined by an FC-4 mapping. Information Units are transferred as a Fibre Channel Sequence.

Intermix A mode of service defined by Fibre Channel that reserves the full Fibre Channel bandwidth for a dedicated Class 1 connection, but also allows connection-less Class 2 traffic to share the link if the bandwidth is available.

Inter switch link A FC connection between switches and/or directors. Also known as ISL.

I/O Input/output

IP Internet Protocol

IPI Intelligent Peripheral Interface

ISL See Inter switch link.

Isochronous Transmission Data transmission which supports network-wide timing requirements. A typical application for isochronous transmission is a broadcast environment which needs information to be delivered at a predictable time.

JBOD Just a bunch of disks.

Jukebox A device that holds multiple optical disks and one or more disk drives, and can swap disks in and out of the drive as needed.

L_Port Loop Port - A node or fabric port capable of performing Arbitrated Loop functions and protocols. NL_Ports and FL_Ports are loop-capable ports.

LAN See Local Area Network - A network covering a relatively small geographic area (usually not larger than a floor or small building). Transmissions within a Local Area Network are mostly digital, carrying data among stations at rates usually above one megabit/s.

Latency A measurement of the time it takes to send a frame between two locations.

LC Lucent Connector. A registered trademark of Lucent Technologies.

Link A connection between two Fibre Channel ports consisting of a transmit fibre and a receive fibre.

Link_Control_Facility A termination card that handles the logical and physical control of the Fibre Channel link for each mode of use.

LIP A Loop Initialization Primitive sequence is a special Fibre Channel sequence that is used to start loop initialization. Allows ports to establish their port addresses.

Local Area Network (LAN) A network covering a relatively small geographic area (usually not larger than a floor or small building). Transmissions within a Local Area Network are mostly digital, carrying data among stations at rates usually above one megabit/s.

Login Server Entity within the Fibre Channel fabric that receives and responds to login requests.

Loop Circuit A temporary point-to-point like path that allows bi-directional communications between loop-capable ports.

Loop Topology An interconnection structure in which each point has physical links to two neighbors resulting in a closed circuit. In a loop topology, the available bandwidth is shared.

LVD Low Voltage Differential

Management Agent A process that exchanges a managed node's information with a management station.

Managed Node A managed node is a computer, a storage system, a gateway, a media device such as a switch or hub, a control instrument, a software product such as an operating system or an accounting package, or a machine on a factory floor, such as a robot.

Managed Object A variable of a managed node. This variable contains one piece of information about the node. Each node can have several objects.

Management Station A host system that runs the management software.

MAR Media Access Rules. Enable systems to self-configure themselves is a SAN environment

Mb/s Megabits per second. Also sometimes referred to as Mbps. In computing terms it is approximately 1,000,000 bits per second. Most precisely it is 1,048,576 (1024 x 1024) bits per second.

MB/s Megabytes per second. Also sometimes referred to as MBps. In computing terms it is approximately 1,000,000 bytes per second. Most precisely it is 1,048,576 (1024 x 1024) bytes per second.

Metadata server In Storage Tank, servers that maintain information (metadata) about the data files and grant permission for application servers to communicate directly with disk systems.

Meter 39.37 inches, or just slightly larger than a yard (36 inches)

Media Plural of medium. The physical environment through which transmission signals pass. Common media include copper and fiber optic cable.

Media Access Rules (MAR).

MIA Media Interface Adapter - MIAs enable optic-based adapters to interface to copper-based devices, including adapters, hubs, and switches.

MIB Management Information Block - A formal description of a set of network objects that can be managed using the Simple Network Management Protocol (SNMP). The format of the MIB is defined as part of SNMP and is a hierarchical structure of information relevant to a specific device, defined in object oriented terminology as a collection of objects, relations, and operations among objects.

Mirroring The process of writing data to two separate physical devices simultaneously.

MM Multi-Mode - See Multi-Mode Fiber

MMF See Multi-Mode Fiber - - In optical fiber technology, an optical fiber that is designed to carry multiple light rays or modes concurrently, each at a slightly different reflection angle within the optical core. Multi-Mode fiber transmission is used for relatively short distances because the modes tend to disperse over longer distances. See also: Single-Mode Fiber, SMF

Multicast Sending a copy of the same transmission from a single source device to multiple destination devices on a fabric. This includes sending to all N_Ports on a fabric (broadcast) or to only a subset of the N_Ports on a fabric (multicast).

Multi-Mode Fiber (MMF) In optical fiber technology, an optical fiber that is designed to carry multiple light rays or modes concurrently, each at a slightly different reflection angle within the optical core. Multi-Mode fiber transmission is used for relatively short distances because the modes tend to disperse over longer distances. See also: Single-Mode Fiber

Multiplex The ability to intersperse data from multiple sources and destinations onto a single transmission medium. Refers to delivering a single transmission to multiple destination Node Ports (N_Ports).

N_Port Node Port - A Fibre Channel-defined hardware entity at the end of a link which provides the mechanisms necessary to transport information units to or from another node.

N_Port Login N_Port Login (PLOGI) allows two N_Ports to establish a session and exchange identities and service parameters. It is performed following completion of the fabric login process and prior to the FC-4 level operations with the destination port. N_Port Login may be either explicit or implicit.

Name Server Provides translation from a given node name to one or more associated N_Port identifiers.

NAS Network Attached Storage - a term used to describe a technology where an integrated storage system is attached to a messaging network that uses common communications protocols, such as TCP/IP.

NDMP Network Data Management Protocol

Network An aggregation of interconnected nodes, workstations, file servers, and/or peripherals, with its own protocol that supports interaction.

Network Topology Physical arrangement of nodes and interconnecting communications links in networks based on application requirements and geographical distribution of users.

NFS Network File System - A distributed file system in UNIX developed by Sun Microsystems which allows a set of computers to cooperatively access each other's files in a transparent manner.

NL_Port Node Loop Port - a node port that supports Arbitrated Loop devices.

NMS Network Management System - A system responsible for managing at least part of a network. NMSs communicate with agents to help keep track of network statistics and resources.

Node An entity with one or more N_Ports or NL_Ports.

Non-Blocking A term used to indicate that the capabilities of a switch are such that the total number of available transmission paths is equal to the number of ports. Therefore, all ports can have simultaneous access through the switch.

Non-L_Port A Node or Fabric port that is not capable of performing the Arbitrated Loop functions and protocols. N_Ports and F_Ports are not loop-capable ports.

Operation A term defined in FC-2 that refers to one of the Fibre Channel *building blocks* composed of one or more, possibly concurrent, exchanges.

Optical Disk A storage device that is written and **read by laser light.**

Optical Fiber A medium and the technology associated with the transmission of information as light pulses along a glass or plastic wire or fiber.

Ordered Set A Fibre Channel term referring to four 10 -bit characters (a combination of data and special characters) providing low-level link functions, such as frame demarcation and signaling between two ends of a link.

Originator A Fibre Channel term referring to the initiating device.

Out of Band Signaling This is signaling that is separated from the channel carrying the information. Also referred to as out-of-band.

Out-of-band virtualization An alternative type of virtualization in which servers communicate directly with disk systems under control of a virtualization function that is not involved in the data transfer.

Peripheral Any computer device that is not part of the essential computer (the processor, memory and data paths) but is situated relatively close by. A near synonym is input/output (I/O) device.

Petard A device that is small and sometimes explosive.

PLDA Private Loop Direct Attach - A technical report which defines a subset of the relevant standards suitable for the operation of peripheral devices such as disks and tapes on a private loop.

PLOGI See N_Port Login

Point-to-Point Topology An interconnection structure in which each point has physical links to only one neighbor resulting in a closed circuit. In point-to-point topology, the available bandwidth is dedicated.

Policy-based management Management of data on the basis of business policies (for example, “all production database data must be backed up every day”), rather than technological considerations (for example, “all data stored on this disk system is protected by remote copy”).

Port The hardware entity within a node that performs data communications over the Fibre Channel.

Port Bypass Circuit A circuit used in hubs and disk enclosures to automatically open or close the loop to add or remove nodes on the loop.

Private NL_Port An NL_Port which does not attempt login with the fabric and only communicates with other NL Ports on the same loop.

Protocol A data transmission convention encompassing timing, control, formatting and data representation.

Public NL_Port An NL_Port that attempts login with the fabric and can observe the rules of either public or private loop behavior. A public NL_Port may communicate with both private and public NL_Ports.

Quality of Service (QoS) A set of communications characteristics required by an application. Each QoS defines a specific transmission priority, level of route reliability, and security level.

Quick Loop is a unique Fibre Channel topology that combines arbitrated loop and fabric topologies. It is an optional licensed product that allows arbitrated loops with private devices to be attached to a fabric.

RAID Redundant Array of Inexpensive or Independent Disks. A method of configuring multiple disk drives in a storage subsystem for high availability and high performance.

Raid 0 Level 0 RAID support - Striping, no redundancy

Raid 1 Level 1 RAID support - mirroring, complete redundancy

Raid 5 Level 5 RAID support, Striping with parity

Repeater A device that receives a signal on an electromagnetic or optical transmission medium, amplifies the signal, and then retransmits it along the next leg of the medium.

Responder A Fibre Channel term referring to the answering device.

Router (1) A device that can decide which of several paths network traffic will follow based on some optimal metric. Routers forward packets from one network to another based on network-layer information. (2) A dedicated computer hardware and/or software package which manages the connection between two or more networks. See also: Bridge, Bridge/Router

SAF-TE SCSI Accessed Fault-Tolerant Enclosures

SAN A Storage Area Network (SAN) is a dedicated, centrally managed, secure information infrastructure, which enables any-to-any interconnection of servers and storage systems.

SAN System Area Network - term originally used to describe a particular symmetric multiprocessing (SMP) architecture in which a switched interconnect is used in place of a shared bus. Server Area Network - refers to a switched interconnect between multiple SMPs.

SANSymphony In-band block-level virtualization software made by DataCore Software Corporation and resold by IBM.

SC Connector A fiber optic connector standardized by ANSI TIA/EIA-568A for use in structured wiring installations.

Scalability The ability of a computer application or product (hardware or software) to continue to function well as it (or its context) is changed in size or volume. For example, the ability to retain performance levels when adding additional processors, memory and/or storage.

SCSI Small Computer System Interface - A set of evolving ANSI standard electronic interfaces that allow personal computers to communicate with peripheral hardware such as disk drives, tape drives, CD_ROM drives, printers and scanners faster and more flexibly than previous interfaces. The table below identifies the major characteristics of the different SCSI version.

SCSI Version	Signal Rate MHz	Bus Width (bits)	Max. DTR (MB/s)	Max. Num. Devices	Max. Cable Length (m)
SCSI-1	5	8	5	7	6
SCSI-2	5	8	5	7	6
Wide SCSI-2	5	16	10	15	6
Fast SCSI-2	10	8	10	7	6
Fast Wide SCSI-2	10	16	20	15	6
Ultra SCSI	20	8	20	7	1.5
Ultra SCSI-2	20	16	40	7	12
Ultra2 LVD SCSI	40	16	80	15	12

SCSI-3 SCSI-3 consists of a set of primary commands and additional specialized command sets to meet the needs of specific device types. The SCSI-3 command sets are used not only for the SCSI-3 parallel interface but for additional parallel and serial protocols, including Fibre Channel, Serial Bus Protocol (used with IEEE 1394 Firewire physical protocol) and the Serial Storage Protocol (SSP).

SCSI-FCP The term used to refer to the ANSI Fibre Channel Protocol for SCSI document (X3.269-199x) that describes the FC-4 protocol mappings and the definition of how the SCSI protocol and command set are transported using a Fibre Channel interface.

Sequence A series of frames strung together in numbered order which can be transmitted over a Fibre Channel connection as a single operation. See also: Exchange

SERDES Serializer Deserializer

Server A computer which is dedicated to one task.

SES SCSI Enclosure Services - ANSI SCSI-3 proposal that defines a command set for soliciting basic device status (temperature, fan speed, power supply status, etc.) from a storage enclosures.

Single-Mode Fiber In optical fiber technology, an optical fiber that is designed for the transmission of a single ray or mode of light as a carrier. It is a single light path used for long-distance signal transmission. See also: Multi-Mode Fiber

SMART Self Monitoring and Reporting Technology

SM Single Mode - See Single-Mode Fiber

SMF Single-Mode Fiber - In optical fiber technology, an optical fiber that is designed for the transmission of a single ray or mode of light as a carrier. It is a single light path used for long-distance signal transmission. See also: MMF

SNIA Storage Networking Industry Association. A non-profit organization comprised of more than 77 companies and individuals in the storage industry.

SN Storage Network. See also: SAN

SNMP Simple Network Management Protocol - The Internet network management protocol which provides a means to monitor and set network configuration and run-time parameters.

SNMWG Storage Network Management Working Group is chartered to identify, define and support open standards needed to address the increased management requirements imposed by storage area network environments.

SSA Serial Storage Architecture - A high speed serial loop-based interface developed as a high speed point-to-point connection for peripherals, particularly high speed storage arrays, RAID and CD-ROM storage by IBM.

Star The physical configuration used with hubs in which each user is connected by communications links radiating out of a central hub that handles all communications.

Storage Tank An IBM file aggregation project that enables a pool of storage, and even individual files, to be shared by servers of different types. In this way, Storage Tank can greatly improve storage utilization and enables data sharing.

StorWatch Expert These are StorWatch applications that employ a 3 tiered architecture that includes a management interface, a StorWatch manager and agents that run on the storage resource(s) being managed. Expert products employ a StorWatch data base that can be used for saving key management data (for example, capacity or performance metrics). Expert products use the agents as well as analysis of storage data saved in the data base to perform higher value functions including -- reporting of capacity, performance, etc. over time (trends), configuration of multiple devices based on policies, monitoring of capacity and performance, automated responses to events or conditions, and storage related data mining.

StorWatch Specialist A StorWatch interface for managing an individual fibre Channel device or a limited number of like devices (that can be viewed as a single group). StorWatch specialists typically provide simple, point-in-time management functions such as configuration, reporting on asset and status information, simple device and event monitoring, and perhaps some service utilities.

Striping A method for achieving higher bandwidth using multiple N_Ports in parallel to transmit a single information unit across multiple levels.

STP Shielded Twisted Pair

Storage Media The physical device itself, onto which data is recorded. Magnetic tape, optical disks, floppy disks are all storage media.

Switch A component with multiple entry/exit points (ports) that provides dynamic connection between any two of these points.

Switch Topology An interconnection structure in which any entry point can be dynamically connected to any exit point. In a switch topology, the available bandwidth is scalable.

T11 A technical committee of the National Committee for Information Technology Standards, titled T11 I/O Interfaces. It is tasked with developing standards for moving data in and out of computers.

Tape Backup Making magnetic tape copies of hard disk and optical disc files for disaster recovery.

Tape Pooling A SAN solution in which tape resources are pooled and shared across multiple hosts rather than being dedicated to a specific host.

TCP Transmission Control Protocol - a reliable, full duplex, connection-oriented end-to-end transport protocol running on top of IP.

TCP/IP Transmission Control Protocol/ Internet Protocol - a set of communications protocols that support peer-to-peer connectivity functions for both local and wide area networks.

Time Server A Fibre Channel-defined service function that allows for the management of all timers used within a Fibre Channel system.

Topology An interconnection scheme that allows multiple Fibre Channel ports to communicate. For example, point-to-point, Arbitrated Loop, and switched fabric are all Fibre Channel topologies.

TL_Port A private to public bridging of switches or directors, referred to as Translative Loop.

Twinax A transmission media (cable) consisting of two insulated central conducting leads of coaxial cable.

Twisted Pair A transmission media (cable) consisting of two insulated copper wires twisted around each other to reduce the induction (thus interference) from one wire to another. The twists, or lays, are varied in length to reduce the potential for signal interference between pairs. Several sets of twisted pair wires may be enclosed in a single cable. This is the most common type of transmission media.

ULP Upper Level Protocols

UTC Under-The-Covers, a term used to characterize a subsystem in which a small number of hard drives are mounted inside a higher function unit. The power and cooling are obtained from the system unit. Connection is by parallel copper ribbon cable or pluggable backplane, using IDE or SCSI protocols.

UTP Unshielded Twisted Pair

Virtual Circuit A unidirectional path between two communicating N_Ports that permits fractional bandwidth.

Virtualization An abstraction of storage where the representation of a storage unit to the operating system and applications on a server is divorced from the actual physical storage where the information is contained.

Virtualization engine Dedicated hardware and software that is used to implement virtualization.

WAN Wide Area Network - A network which encompasses inter-connectivity between devices over a wide geographic area. A wide area network may be privately owned or rented, but the term usually connotes the inclusion of public (shared) networks.

WDM Wave Division Multiplexing - A technology that puts data from different sources together on an optical fiber, with each signal carried on its own separate light wavelength. Using WDM, up to 80 (and theoretically more) separate wavelengths or channels of data can be multiplexed into a stream of light transmitted on a single optical fiber.

WEBM Web-Based Enterprise Management - A consortium working on the development of a series of standards to enable active management and monitoring of network-based elements.

Zoning In Fibre Channel environments, the grouping together of multiple ports to form a virtual private storage network. Ports that are members of a group or zone can communicate with each other but are isolated from ports in other zones.

Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this redbook.

IBM Redbooks

- *Designing and Optimizing an IBM Storage Area Network*, SG24-6419
- *Designing and Optimizing an IBM Storage Area Network Featuring the IBM 2109 and 3534*, SG24-6426
- *Designing an IBM Storage Area Network*, SG24-5758
- *Introduction to SAN Distance Solutions*, SG24-6408
- *Introducing Hosts to the SAN fabric*, SG24-6411
- *Implementing an Open IBM SAN,* SG24-6116
- *Implementing an Open IBM SAN Featuring the IBM 2109, 3534-1RU, 2103-H07*, SG24-6412
- *Introduction to Storage Area Network, SAN*, SG24-5470
- *IP Storage Networking: IBM NAS and iSCSI Solutions*, SG24-6240
- *The IBM TotalStorage NAS 200 and 300 Integration Guide*, SG24-6505
- *Implementing the IBM TotalStorage NAS 300G: High Speed Cross Platform Storage and Tivoli SANergy!*, SG24-6278
- *iSCSI Performance Testing & Tuning*, SG24-6531
- *Using iSCSI Solutions' Planning and Implementation*, SG24-6291
- *Storage Networking Virtualization: What's it all about?*, SG24-6210
- *IBM Storage Solutions for Server Consolidation*, SG24-5355
- *Implementing the Enterprise Storage Server in Your Environment*, SG24-5420
- *Implementing Linux with IBM Disk Storage*, SG24-6261
- *Storage Area Networks: Tape Future In Fabrics*, SG24-5474
- *IBM Enterprise Storage Server*, SG24-5465

Other resources

These publications are also relevant as further information sources:

- *Building Storage Networks*, ISBN 0072120509

These IBM publications are also relevant as further information sources:

- *ESS Web Interface User's Guide for ESS Specialist and ESS Copy Services*, SC26-7346
- *IBM Storage Area Network Data Gateway Installation and User's Guide*, SC26-7304
- *IBM Enterprise Storage Server Configuration Planner*, SC26-7353
- *IBM Enterprise Storage Server Quick Configuration Guide*, SC26-7354
- *IBM SAN Fibre Channel Managed Hub 3534 Service Guide,* SY27-7616
- *IBM Enterprise Storage Server Introduction and Planning Guide, 2105 Models E10, E20, F10 and F20*, GC26-7294
- *IBM Enterprise Storage Server User's Guide, 2105 Models E10, E20, F10 and F20*, SC26-7295
- *IBM Enterprise Storage Server Host Systems Attachment Guide, 2105 Models E10, E20, F10 and F20*, SC26-7296
- *IBM Enterprise Storage Server SCSI Command Reference, 2105 Models E10, E20, F10 and F20*, SC26-7297
- *IBM Enterprise Storage Server System/390 Command Reference, 2105 Models E10, E20, F10 and F20*, SC26-7298
- *IBM Storage Solutions Safety Notices*, GC26-7229
- *PCI Adapter Placement Reference, SA38-0583*
- *Translated External Devices/Safety Information*, SA26-7003
- *Electrical Safety for IBM Customer Engineers*, S229-8124

Referenced Web sites

These Web sites are also relevant as further information sources:

- IBM TotalStorage hardware, software and solutions:

  `http://www.storage.ibm.com`

- IBM TotalStorage Storage Networking:

  `http://www.storage.ibm.com/snetwork/index.html`

- Brocade:

  `http://www.brocade.com`
- QLogic:

  `http://www.qlogic.com`
- Emulex:

  `http://www.emulex.com`
- Finisar:

  `http://www.finisar.co`
- Veritas:

  `http://www.veritas.co`
- Tivoli:

  `http://www.tivoli.co`
- JNI:

  `http://www.Jni.com`
- IEEE:

  `http://www.ieee.org`
- Storage Networking Industry Association:

  `http://www.snia.org`
- Fibre Channel Industry Association:

  `http://www.fibrechannel.com`
- SCSI Trade Association:

  `http://www.scsita.org`
- Internet Engineering Task Force:

  `http://www.ietf.org`
- American National Standards Institute:

  `http://www.ansi.org`
- Technical Committee T10:

  `http://www.t10.org`
- Technical Committee T11:

  `http://www.t11.org`
- eServer xSeries 430 and NUMA-Q Information Center

  `http://webdocs.numaq.ibm.com`

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IBM SAN Survival Guide Featuring the IBM 3534 and 2109

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250 <-> 459 pages

IBM SAN Survival Guide Featuring the IBM 3534 and 2109

Protect your data with an IBM SAN

Build a SAN too tough to die

Survive and conquer

As we all know, large ocean going ships never collide with icebergs. However, occasionally life deals out some unexpected pleasures for us to cope with. Surviving any disaster in life is usually a lot easier if you have prepared adequately by taking into account the likely problems, solutions, and their implementation.

In this IBM Redbook, we limit ourselves to those situations in which it is likely that a SAN will be deployed. We present the IBM TotalStorage SAN Fibre Channel Switch 2109 and 3534-F08, going under the surface to show the fault tolerant features that they utilize, and then describe solutions with all these features taken into account. Each of these solutions was built on practical experience, in some cases with cost in mind, in some cases with no cost in mind. Any well thought out SAN design will have taken each of these concerns into account, and either formulated a solution for it, or ignored it, but nonetheless understanding the potential exposure.

With these points in mind, in this redbook we have two objectives: to position the IBM SAN products that are currently in our portfolio; and to show how those products can be configured together to build a SAN that not only allows you to survive most forms of disaster, but also provides performance benefits. So, make sure that you know what to do if you hit an iceberg!

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