

# *Compaq StorageWorks*

## **Application Note**

### *Combining 16-Port Switches to Construct Higher Port Count Switches*

---

*Visit Our Web Site for the Latest Information.*

*At Compaq, we are continually making additions to our storage solution product line. Please check our web site for more information on our Fibre Channel product line as well as the latest drivers, technical tips, and updates to this application note and other documentation. Visit our web site at: <http://www.compaq.com/storageworks>*

---

First Edition (April 2001)

Part Number: AA-RPH8A-TE

**Compaq Computer Corporation**

© 2001 Compaq Computer Corporation.

Compaq, the Compaq logo, and StorageWorks Registered in U. S. Patent and Trademark Office.

SANworks, Tru64 UNIX, and OpenVMS are trademarks of Compaq Information Technologies Group, L.P. in the United States and other countries.

Microsoft, MS-DOS, Windows, Windows NT are trademarks of Microsoft Corporation in the United States and other countries.

Intel, Pentium, Intel Inside, and Celeron are trademarks of Intel Corporation in the United States and other countries.

Motif, OSF/1, UNIX, the "X" device, IT DialTone, and The Open Group are trademarks of The Open Group in the United States and other countries.

All other product names mentioned herein may be trademarks of their respective companies.

Confidential computer software. Valid license from Compaq required for possession, use or copying. Consistent with FAR 12.211 and 12.212, Commercial Computer Software, Computer Software Documentation, and Technical Data for Commercial Items are licensed to the U.S. Government under vendor's standard commercial license.

Compaq shall not be liable for technical or editorial errors or omissions contained herein. The information in this document is provided "as is" without warranty of any kind and is subject to change without notice. The warranties for Compaq products are set forth in the express limited warranty statements accompanying such products. Nothing herein should be construed as constituting an additional warranty.

Compaq service tool software, including associated documentation, is the property of and contains confidential technology of Compaq Computer Corporation. Service customer is hereby licensed to use the software only for activities directly relating to the delivery of, and only during the term of, the applicable services delivered by Compaq or its authorized service provider. Customer may not modify or reverse engineer, remove, or transfer the software or make the software or any resultant diagnosis or system management data available to other parties without Compaq's or its authorized service provider's consent. Upon termination of the services, customer will, at Compaq's or its service provider's option, destroy or return the software and associated documentation in its possession.

Printed in the U.S.A.

Combining 16-Port Switches to Construct Higher Port Count Switches  
Application Note  
First Edition (April 2001)  
Part Number: AA-RPH8A-TE

## Introduction

Storage Area Networks (SANs) are fast becoming the standard storage infrastructure for connecting storage and servers. Initially SAN fabrics were implemented as small islands of a few switches connecting a limited number of servers, storage subsystems and other devices.

As the SAN technology matures, Compaq is leading the way in supporting larger SAN fabrics. Earlier this year Compaq showed leadership by announcing support for up to twenty switches in a SAN fabric. Larger switch counts increase the complexity of designing, installing and maintaining SAN fabrics.

To enable our customers to implement these larger SAN fabrics, Compaq released the StorageWorks Heterogeneous Open SAN Design Reference Guide. The SAN Design Guide is available on the World Wide Web at:

<http://www.compaq.com/products/storageworks/techdoc/san/AA-RMPNA-TE.html>

Refer to the SAN Design Guide for more detailed information on how to design SANs.

Compaq is now providing the next step in easily deployed SAN solutions with the StorageWorks SAN Switch Integrated/32 and 64. The SAN Switch Integrated/32 and 64 are groups of multiple switches configured in a single chassis as either a 32 or 64 port switch. This document provides examples and information for building a higher port count switch from existing 16-port switches. Using this technique, Compaq is protecting the customer's investment in 16-port switches as a SAN fabric is expanded.

## Scope

This document is not a replacement for the Heterogeneous Open SAN Design Reference Guide. It is intended to provide practical examples of integrated higher port count switches. This document describes Compaq standard Tree Backbone SAN designs for integrated 32, 64, 96 and 128 port switches. These integrated switches are built from existing Compaq 16-port switches. New information introduced in this document will be incorporated in an updated release of the Heterogeneous Open SAN Design Reference guide.

SAN design projects involve many design choices and trade-offs. Therefore this document attempts to provide a greater understanding of SAN design theory. This understanding is meant to enable someone to choose the appropriate design alternatives to meet the requirements of a moderately sized SAN.

Building custom, complex, or very large SAN networks may require advanced SAN design skills to identify and resolve SAN issues. This document does not address such skills or issues.

## Minimum Requirements

The following requirements are necessary in order for proper operation of the SAN designs described in this document.

- All switches must be running the same version of firmware
- Only Compaq StorageWorks SAN Switch 8/16 and 8/16-EL model switches are supported.

## Basic Terminology

This section describes a common set of terms to identify the base components of the SAN infrastructure. There are many different names used throughout the industry for the same components. The following figure and descriptions will be referenced throughout the remainder of this document.

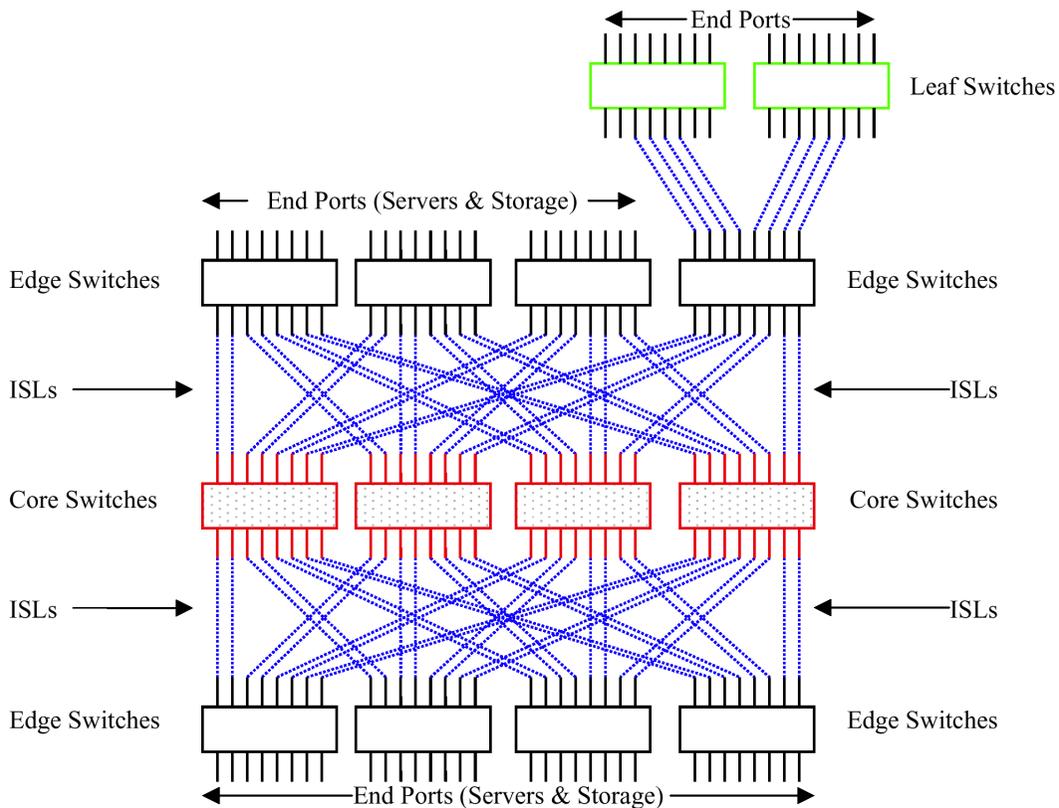


Figure 1. SAN Infrastructure Components (64-Port Fat Tree Configuration)

### Core Switch

The switches in the center level of the diagram that connect between edge switches are called core switches. “Central” or “Backbone” switches are other common terms used to identify a core switch. Ports on core switches are generally used to connect other switches together. In some configurations the unused ports on core switches are used as end ports. Centralized backup is an example of a SAN design that connects storage devices directly to the core switches in the SAN.

### Edge Switch

A switch on the edge of the backbone or tree fabric is called an edge switch. These switches can be used to connect servers, storage subsystems and other devices to the SAN fabric or to another level of switches.

### **Leaf Switch**

A leaf switch is a term used for a switch connected to the edge switches of a tree or backbone fabric. A leaf switch that is primarily used in a Ring topology is also called a satellite switch.

### **End Ports**

Switch ports that are used to connect to a server, storage subsystem or storage device are called end ports or device ports.

### **Inter-Switch Link (ISL)**

An Inter-Switch Link or ISL is the cable that connects two switch ports together.

## **Tree Backbone Fabrics**

A Tree Backbone SAN Fabric is a three-level configuration of switches where the center level switches are dedicated as core or backbone switches. These core or backbone switches connect the edge switches on the upper and lower tiers in the fabric. Servers and storage subsystems can be connected to and intermixed with any of the edge switches.

Fat trees and skinny trees are the two forms of backbone topologies. The main difference between fat and skinny trees is the number of ISLs used to connect the edge switches to the core switches. The number of ISLs reduces the number of end ports and therefore affects the total number of switches needed for a particular configuration. Fat trees use 50% of the edge switch ports as ISLs while skinny trees use less than 50%. This distinction in the number of ISLs between fat and skinny trees results in two major differences:

1. Skinny trees require fewer switches than fat trees to supply the same number of end ports. For example six 16-port switches in a skinny tree configuration yield 64 ports while the same six switches in a fat tree configuration yield only 32 end ports.
2. Fat trees have more ISL connections and therefore have larger cross sectional bandwidth capabilities than skinny trees. The term cross sectional bandwidth is used to refer to the maximum amount of data that can pass through the ISL connections at the midpoint of the fabric.

The previous figure (Figure 1) depicts a 64-port fat tree. This configuration has 12 switches, 4 of which are dedicated as core switches and 8 edge switches. The 8 edge switches each have 8 available end ports to connect to servers or storage. In contrast the following figure (Figure 2) depicts 6 switches configured as a 64-port skinny tree.

6 **Combining 16-Port Switches to Construct Higher Port Count Switches**

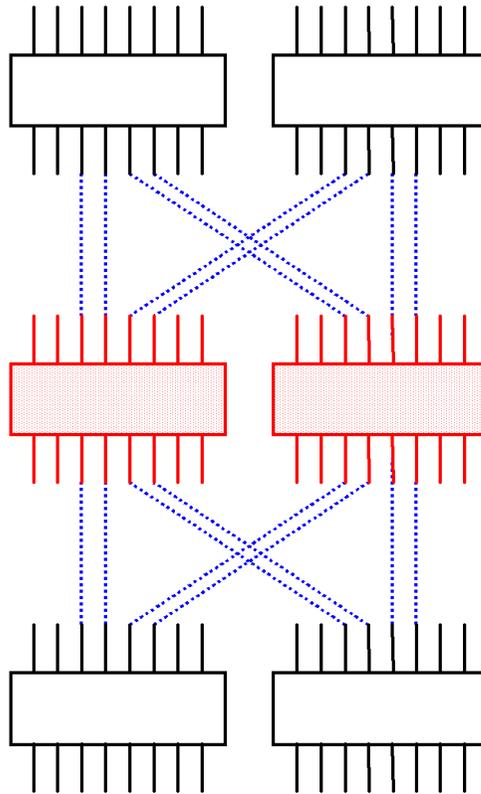


Figure 2. 64-Port Skinny Tree

This configuration has 6 switches, 2 of which are core switches and 4 edge switches. The 4 edge switches each have 12 available end ports to connect to servers or storage. With the 48 ports on the edge switches and with the 16 available ports on the core switches the total number of end ports is 64.

In some views, switches with end-ports are not core switches. Since the primary function of the central switches in this example is to connect the other switches together, it is valid to call them core switches. If the configuration is expanded as shown in the next figure (Figure 3) then it is even more clear that these switches are core switches.

This configuration can be expanded to 10 switches that will yield a 96-port skinny tree as shown in the figure below.

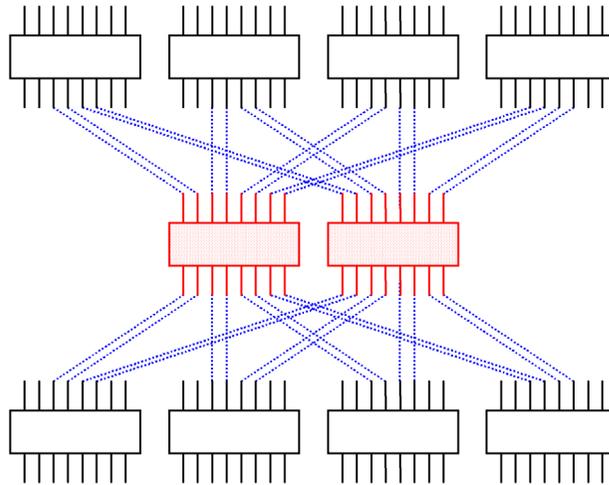


Figure 3. 96-Port Skinny Tree

As stated earlier, the primary difference between skinny and fat trees is the ratio of end ports to ISL connections. In a fat tree configuration (Figure 1) edge switches have 8 end ports and 8 ISL connections for a ratio of 1 end port per ISL. In the skinny tree configuration (Figure 3) edge switches have 12 end ports and 4 ISL connections for a ratio of 3 end ports per ISL. The number of ISL ports is generally driven by the need for cross-sectional SAN bandwidth.

For the SAN fabric, the more cross-sectional SAN bandwidth required, the more ISL connections that are needed. The SAN fabric must have enough ISL connections to limit contention or oversubscription for these ISL connections and also to provide the expected cross-sectional bandwidth. Contention or oversubscription for ISL connections is simply describing the funnel effect of many ports trying to traverse a limited number of ISL connections. If you have 12 end ports on an edge switch trying to transfer data to other switches and only 4 ISLs then your ISL connections have a 3 to 1 oversubscription. There are 3 end ports contending for each ISL connection.

Skinny tree configurations which have more input ports (end ports) than output ports (ISLs) are more likely to suffer from oversubscription than fat trees, which have double the number of ISLs.

## Factors to Consider: Planning # of ISLs

How do you determine the proper number of ISL connections in designing the appropriate SAN configuration for a given set of requirements? There are many factors to consider, however, the primary design considerations for the number of ISL connections are:

- [Data Locality](#)
- [Connectivity](#)
- [Performance/Application Workloads](#)

There is more information available on this topic in the SAN Design Guide.

## Data Locality

A major factor in determining the optimal SAN topology design is the desired or required location or method of storage deployment. Storage deployment should be based on the specific application requirements for data locality or placement of data:

- Local: One-to-One
- Centralized in a single storage pool or centralized pools: Many-to-One
- Distributed among storage pools throughout the fabric: Many-to-Many

Local or One-to-One has the primary data access between servers and storage connected to the same switch. Centralized or Many-to-One has many servers connected to different switches primarily accessing a centrally located storage pool. Distributed or Many-to-Many is where data access varies between many different servers connected to different switches and many different storage systems connected to different switches. Many-to-Many data access is conducive to applications or deployments that implement distributed SAN-wide storage pooling and sharing.

Selection of the appropriate SAN topology design should primarily be based on the expected primary data locality need, however, consideration should also be given to corporate, departmental, and organizational requirements relative to data grouping and accessibility.

## Connectivity

Connectivity needs directly affect the total number of switches required. The total number of ports required for connectivity of servers and storage is a major consideration when evaluating different SAN topology designs. If the connectivity requirements are increasing with time then choose an initial design that can be scaled or migrated to a topology design with more ports. Your design should also provide adequate number of ISL connections for both the initial design and the planned migration. Planning sufficient ISLs for future needs will minimize the reconfiguration of existing switches when migrating to a new design.

If the total number of ports required exceeds a given topology design, you should consider higher capacity topologies or multiple independent SANs.

## Performance/Application Workloads

Performance requirements need to be considered in any SAN fabric design. This can be difficult, because data traffic in a SAN is not always predictable. Consider the types of applications that will be utilized on the SAN relative to data locality classification. Applications can usually be classified as high bandwidth or high throughput. What is important is that any particular design choice will provide an adequate level of performance based on the data locality classification of the major applications being utilized.

Other factors to consider are the locality of data in relation to the servers most likely to access the data and the number and placement of ISLs between switches in the fabric.

## Oversubscription

All Compaq SAN switches implement a non-blocking design. That is, any two ports can be active and transfer data without impacting the data transfer between any other ports.

Oversubscription, contention or congestion can occur when data from multiple ports must be sent to a single destination port, or when data is required to traverse an ISL from multiple input ports. In situations where this occurs, the Fibre Channel switches will interleave frames from multiple ports, thus giving fractional bandwidth to all devices. If this occurs often enough, overall performance may be reduced. For large data transfers, this means that the maximum guaranteed bandwidth through the ISL is approximately 100 MB/sec divided by the number of users of that ISL.

Oversubscription can be minimized by ensuring that the fabric design provides for an adequate number of ISLs and that scenarios where many ports are attempting to access a single port are minimized. As mentioned before, skinny tree configurations have a higher potential for oversubscription because they have fewer ISL connections than fat tree. Another factor that may affect the overall performance of the SAN fabric is the routing algorithm used by the switch for multiple ISL paths.

## Multiple ISL Routing Algorithm

It is possible to reduce oversubscription by utilizing multiple ISL connections between switches. With the current version of switch firmware Compaq Fibre Channel switches implement a static routing algorithm. For most applications, this routing algorithm will not have any performance implications. Currently, very high bandwidth configurations require either dedicated ISL connections or periodic monitoring of ISL performance in order to see if significant oversubscription is present.

The current routing algorithm is a “Fabric Shortest Path First”, round-robin based architecture for each source–destination port pair. In other words, when two ports want to communicate for the first time the shortest path (least number of hops) is determined. If multiple paths of equal distance are available the paths are assigned on a round-robin basis. Once a path is assigned for a pair of ports the same path is used until a failure forces an alternative path to be found. The following diagram (Figure 4) illustrates the routing process.

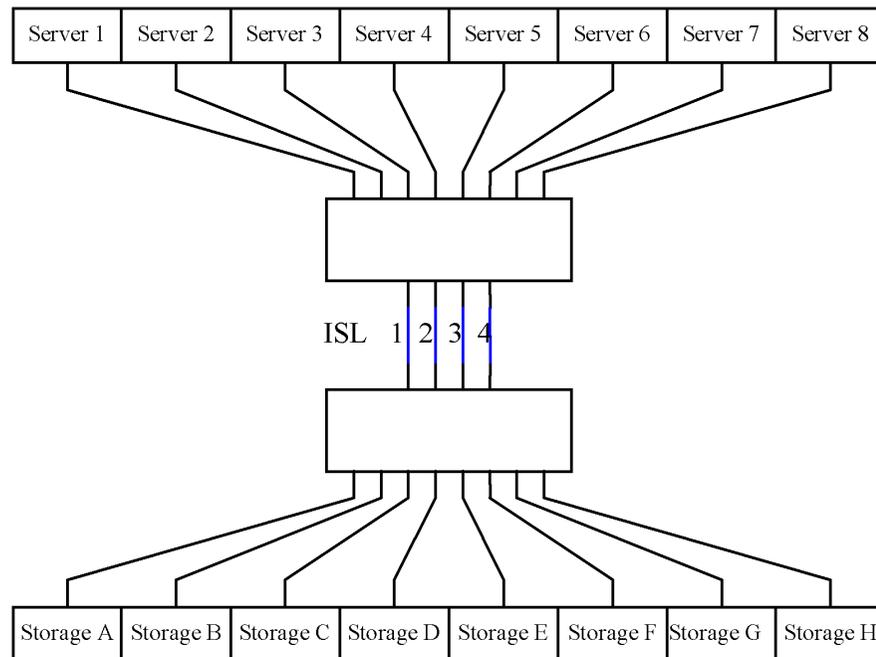


Figure 4. ISL Routing Algorithm

Assume that Server 1 talks to Storage A, Server 2 talks to Storage B and so on for all servers and that they also log on to the fabric in numerical order. The four routing paths are all equal distance (one switch hop) so the paths are assigned on a round-robin basis. Servers 1 and 5 would be routed over ISL 1, Servers 2 and 6 over ISL 2, Servers 3 and 7 over ISL3, and Servers 4 and 8 over ISL 4. If Servers 1 and 5 are the primary servers using more bandwidth than other servers on the SAN, then an optimal configuration would need to modify the routing for these two servers. The routing is currently static, meaning that once the route is determined at fabric login, the route remains in effect until a failure happens that forces a fabric reconfiguration.

This static routing strategy with no performance considerations can cause performance problems for custom SAN designs or large very high bandwidth applications. Given the current static routing strategy, it may be necessary to monitor the performance of the path and manually adjust the routes for custom SAN designs or large very high bandwidth applications. For the majority of configurations and applications, this static routing algorithm will not impact performance.

## Modifying ISL Port Routing

ISL oversubscription will not affect the majority of properly-sized SAN fabrics, so this is not a routine maintenance task. While it is technically easy to modify the routing paths, this is not a task that the inexperienced person wants to attempt. This functionality should be reserved for custom SAN designs and should only be done by qualified SAN design engineers. Without a complete understanding of the locality of the data, it is possible to reduce performance and even create loops by changing the routing paths.

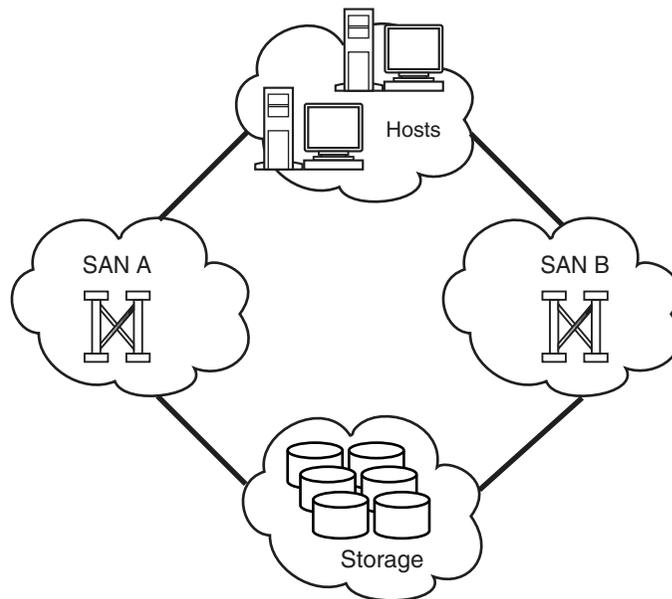
The performance of the switch ports can be monitored using either the GUI or via Telnet with the **portPerfShow** command.

Once a port is determined to be “over-subscribed” then the next step is to determine what traffic is going through that port and whether it can be re-routed over a different port. The **uRouteShow** command will display on a port-by-port basis for each destination domain which output port will be used.

Never re-route a path to a path with a longer hop count, this is the easiest way to cause a routing loop and lose data packets. The **uRouteConfig port#, domain#, output\_port#** command is used to modify the route. In this command, **port#** is the port that you are modifying the route for. Likewise **domain#** is the destination domain of the route you wish to change and the **output\_port#** is the new output port that this port should use to reach the destination domain.

## Availability

Availability is a key design attribute of all SAN fabrics. A significant factor in designing a highly available fabric is the elimination of all potential single points of failure. For this reason, for all but the very smallest SAN fabrics, Compaq recommends that a SAN be implemented with dual redundant SAN fabrics. There is no hardware component shared between two redundant SAN fabrics.



SHR-2214A

Figure 5. Redundant SAN Fabrics

With two completely separate SAN fabrics there are no single points of failure, including software failures. With two fabrics, it is possible to upgrade one fabric while the other fabric is still in use, avoiding downtime during maintenance.

## Switch Parameters

When there are multiple switches in a fabric, each switch must have the same switch parameter set with the exception of three unique parameters, switch name, IP address and Domain ID. Compaq recommends that the switch name match the network name associated with the switch IP address. For example, if the IP name is SANSwitch1.xyz.com, then the Switch Name should be SANSwitch1. The Domain ID must be set to a number between 1 and 239 and a popular way of numbering it is to use the last octet of the IP address. For example, if the IP address of SANSwitch1 is 10.6.6.100, then the Domain ID for that switch will be 100.

To set the switch parameters, connect to the switch using the serial port (or front panel if available) to set the IP address, subnet mask and default gateway of the switch. Once the IP address information is set, then Telnet to the switch login to the “admin” account. Verify the IP information and set the rest of the switch parameters via the **configure**, **iodset** and **diagDisablePost** commands. The following is a sample screen capture. For the specific settings of a particular Compaq SAN switch use the documentation supplied with the hardware.

Fabric OS (tm) Release v2.1.9g

```
login: admin
Password:
Switch:admin> ipaddrshow
Ethernet IP Address: 10.6.6.44
Ethernet Subnetmask: 255.255.255.0
```

## 12 Combining 16-Port Switches to Construct Higher Port Count Switches

```
Fibre Channel IP Address: none
Fibre Channel Subnetmask: none
Gateway Address:
Switch:admin> switchName "SANSwitch1"
SANSwitch1:admin> switchdisable
SANSwitch1:admin> configure
```

Configure...

Fabric parameters (yes, y, no, n): [no] [y](#)

```
Domain: (1..239) [1] 44
BB credit: (1..16) [16]
R_A_TOV: (4000..120000) [10000]
E_D_TOV: (1000..5000) [2000]
Data field size: (256..2112) [2112]
Non-SCSI Tachyon Mode: (0..1) [0]
Disable Device Probing: (0..1) [0]
Suppress Class F Traffic: (0..1) [0]
SYNC IO mode: (0..1) [0]
VC Encoded Address Mode: (0..1) [0]
Per-frame Route Priority: (0..1) [0]
```

Virtual Channel parameters (yes, y, no, n): [no] [y](#)

```
VC Priority 2: (2..3) [2]
VC Priority 3: (2..3) [2]
VC Priority 4: (2..3) [2]
VC Priority 5: (2..3) [2]
VC Priority 6: (2..3) [3]
VC Priority 7: (2..3) [3]
```

Arbitrated Loop parameters (yes, y, no, n): [no] [y](#)

```
Send FAN frames?: (0..1) [1]
Always Send RSCN?: (0..1) [1]
Do Not Allow AL_PA 0x00?: (0..1) [0]
QuickLoop Soft Init?: (0..1) [0]
```

System services (yes, y, no, n): [no] [y](#)

```
rstatd (on, off): [off]
rusersd (on, off): [off]
Disable RLS probing (on, off): [on]
```

Committing configuration...

done.

```
SANSwitch1:admin> switchenable
```

```
SANSwitch1:admin> iodset
```

Committing configuration...

done.

```
SANSwitch1:admin>
```

```
SANSwitch1:admin> diagDisablePost
```

```
SANSwitch1:admin>
```

## Verify ISL Cables

After all the switch parameters are set then the next task is to verify that the ISL cables are all connected properly. Telnet to each switch and execute the **switchShow** command and verify that the ports for each switch are interconnected correctly for the intended configuration.

```
StarBase1_W:admin> switchshow
switchName:      StarBase1_W
switchType:      5.4
switchState:     Online
switchRole:      Subordinate
switchDomain:    110
switchId:        fffc6e
switchWwn:       10:00:00:60:69:12:16:6b
port 0: id Online      E-Port 10:00:00:60:69:12:0f:4d "StarBase1_NW"
port 1: id Online      E-Port 10:00:00:60:69:12:0f:4d "StarBase1_NW"
port 2: id Online      E-Port 10:00:00:60:69:12:0f:4d "StarBase1_NW"
port 3: id Online      E-Port 10:00:00:60:69:12:0f:4d "StarBase1_NW"
port 4: id Online      E-Port 10:00:00:60:69:12:16:e6 "StarBase1_SW" (upstream)
port 5: id Online      E-Port 10:00:00:60:69:12:16:e6 "StarBase1_SW"
port 6: id Online      E-Port 10:00:00:60:69:12:16:e6 "StarBase1_SW"
port 7: id Online      E-Port 10:00:00:60:69:12:16:e6 "StarBase1_SW"
port 8: id Online      E-Port 10:00:00:60:69:12:14:bb "StarBase1_NE"
port 9: id Online      E-Port 10:00:00:60:69:12:14:bb "StarBase1_NE"
port 10: id Online     E-Port 10:00:00:60:69:12:14:bb "StarBase1_NE"
port 11: id Online     E-Port 10:00:00:60:69:12:14:bb "StarBase1_NE"
port 12: id Online     E-Port 10:00:00:60:69:12:14:1e "StarBase1_SE"
port 13: id Online     E-Port 10:00:00:60:69:12:14:1e "StarBase1_SE"
port 14: id Online     E-Port 10:00:00:60:69:12:14:1e "StarBase1_SE"
port 15: id Online     E-Port 10:00:00:60:69:12:14:1e "StarBase1_SE"
```

The **fabricShow** command should be used to verify that each switch in the configuration can see all other neighboring switches in the configuration.

## Cable Issues

**Cable Dressing:** When routing fiber optic cables pay close attention to ensure that you do not exceed the recommended bend radius. For multi-mode fiber and single-mode cable the minimum bend radius is 25 mm. When cables are bundled or hanging unsupported, use Velcro tie wraps to group and support the cables. Never use plastic tie wraps as they can damage the internal fiber core if over-tightened.

**Cable Interference:** Excess cable should be dressed in an area that does not interfere with removal and replacement of a switch, or obscure viewing visual indicators on the switch. Ensure that the dressing and routing of the cables allows for removal and replacement of a switch without requiring disconnecting cables from any other switch or removing any other component.

**Cable Symmetry:** When connecting cables, consider slot/port-numbering symmetry. Be consistent across similar servers with cabling in terms of HBA slot placement and cabling to switches. If configuring with two SAN fabrics and multi-path support, connect HBA 1 to SAN Fabric 1, HBA 2 to SAN Fabric 2, etc. Cable symmetry is not a requirement, but serves as an aid to troubleshooting.

**ISL Cables:** ISL cables should, at a minimum, be labeled with a unique color and, if possible, use a different color cable. ISL cabling should use the same ports on each switch in order to make cabling and troubleshooting easier.

**Labels:** Define a system for cable labeling. Even a small SAN can include a very high number of fiber optic interconnect cables. Label both ends of each cable with the same unique cable number and color code scheme. This will allow you to quickly identify each cable uniquely. Also place a label at each end of the cables that identifies connection points at both ends, such as “TO” and “FROM”. Use label types that are easy to create and read, and ensure they are attached securely to the cable.

**Recording:** As you construct the SAN, record the cable connections and mark this information on the configuration layout diagram. Record the World Wide ID (WWID) of all nodes and devices and identify where they physically reside. It is recommended that you place a label on each Fibre Channel HBA with the WWID clearly identified. Compaq storage systems are pre-labeled with this information; however, you may wish to place an additional label on the front of the unit in plain view.

**Routing:** For very high availability configuration, the redundant set of Fibre Channel cables should not take the same path to the destination. If both fiber cables are in the same conduit and the conduit gets cut, then both paths are lost at the same time.

## Configuration Clear and Save

Before adding new switches to an existing SAN, it is a good practice to clear the saved zone configuration information from the flash memory of each new switch. In order to clear and save the zoning information, Telnet to each switch. Issue the **cfgclear** and then the **cfgsave** command on each new switch before connecting it to the existing SAN fabric.

Be care full not to issue these commands on a running SAN Fabric as it will delete all the relevant zoning information for the fabric.

## Zoning

At this point everything for the SAN fabric should be set up, with the exception of any required zoning. The SAN Design Guide has all the rules regarding what Operating Systems must be in separate zones from what other Operating System software.

## 32-Port Fat Tree – High Bandwidth

Figure 6 is a logical representation of six 16-port Compaq Fibre Channel switches configured as an integrated 32-Port high bandwidth switch.

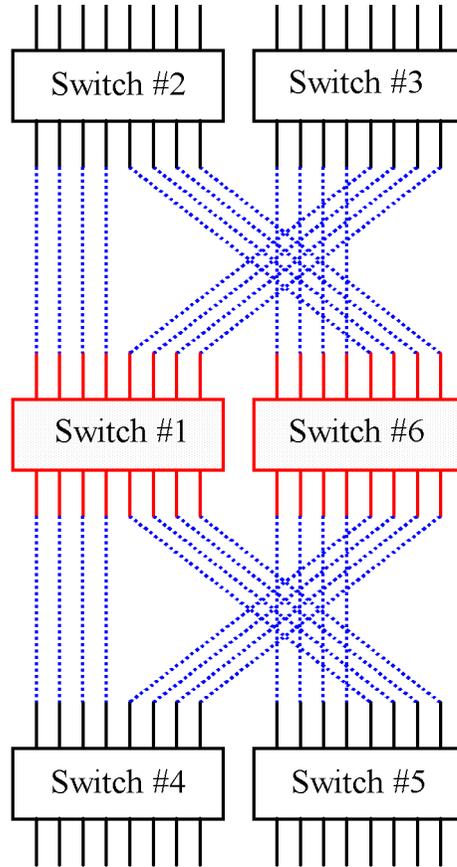


Figure 6. 32-Port High Bandwidth Configuration

**NOTE:** This configuration is the same as for the Compaq SAN Switch Integrated/32.

## 16 Combining 16-Port Switches to Construct Higher Port Count Switches

**NOTE:** Figure 6 is a logical representation of the switches in this configuration. The following table lists the physical ISL cables with the source and destination port for the 32-Port high bandwidth configuration.

**Table 1: 32-Port High Bandwidth ISL Connections**

Port	Switch #1	Switch #2	Switch #3	Switch #4	Switch #5	Switch #6
0	SW. #2 Port 8	User Port	User Port	User Port	User Port	SW. #5 Port 12
1	SW. #2 Port 9	User Port	User Port	User Port	User Port	SW. #5 Port 13
2	SW. #2 Port 10	User Port	User Port	User Port	User Port	SW. #5 Port 14
3	SW. #2 Port 11	User Port	User Port	User Port	User Port	SW. #5 Port 15
4	SW. #3 Port 8	User Port	User Port	User Port	User Port	SW. #4 Port 12
5	SW. #3 Port 9	User Port	User Port	User Port	User Port	SW. #4 Port 13
6	SW. #3 Port 10	User Port	User Port	User Port	User Port	SW. #4 Port 14
7	SW. #3 Port 11	User Port	User Port	User Port	User Port	SW. #4 Port 15
8	SW. #4 Port 8	SW. #1 Port 0	SW. #1 Port 4	SW. #1 Port 8	SW. #1 Port 12	SW. #3 Port 12
9	SW. #4 Port 9	SW. #1 Port 1	SW. #1 Port 5	SW. #1 Port 9	SW. #1 Port 13	SW. #3 Port 13
10	SW. #4 Port 10	SW. #1 Port 2	SW. #1 Port 6	SW. #1 Port 10	SW. #1 Port 14	SW. #3 Port 14
11	SW. #4 Port 11	SW. #1 Port 3	SW. #1 Port 7	SW. #1 Port 11	SW. #1 Port 15	SW. #3 Port 15
12	SW. #5 Port 8	SW. #6 Port 12	SW. #6 Port 8	SW. #6 Port 4	SW. #6 Port 0	SW. #2 Port 12
13	SW. #5 Port 9	SW. #6 Port 13	SW. #6 Port 9	SW. #6 Port 5	SW. #6 Port 1	SW. #2 Port 13
14	SW. #5 Port 10	SW. #6 Port 14	SW. #6 Port 10	SW. #6 Port 6	SW. #6 Port 2	SW. #2 Port 14
15	SW. #5 Port 11	SW. #6 Port 15	SW. #6 Port 11	SW. #6 Port 7	SW. #6 Port 3	SW. #2 Port 15

**NOTE:** Table 1 has each switch listed by column and each port of a switch listed by row. The contents of a table cell indicates the switch and port numbers that directly connect to the given switch and port number via an ISL. A port on a switch that is not used as an ISL is labelled a user port. For example, switch 1 port 0 is connected by an ISL to switch 2 port 8. Switch 2 port 7 is a user port that is not used as an ISL and that is available for a server or storage connection.

## 64-Port Skinny Tree – High Connectivity

Figure 7 is a logical representation of six 16-port Compaq Fibre Channel switches configured as an integrated 64-Port high connectivity switch.

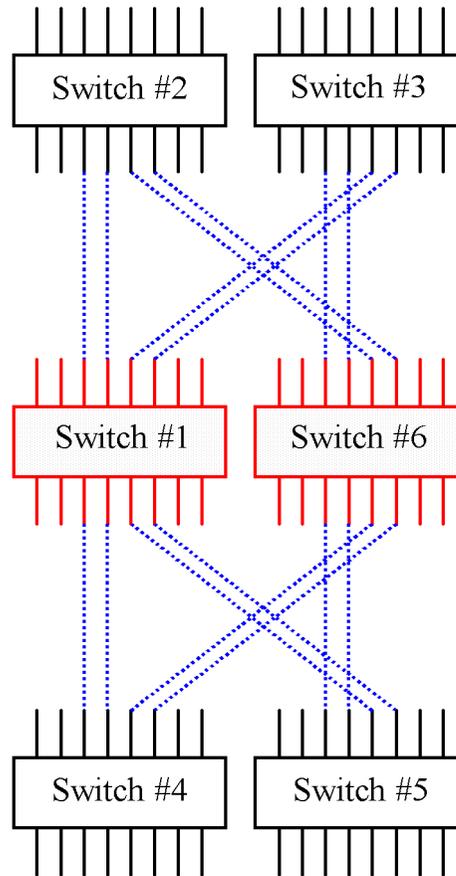


Figure 7. 64-Port High Connectivity Configuration

**NOTE:** This configuration is the same as for the Compaq SAN Switch Integrated/64.

**18 Combining 16-Port Switches to Construct Higher Port Count Switches**

**NOTE:** Figure 7 is a logical representation of the switches in this configuration. The following table lists the physical ISL cables with the source and destination port used for the 64-Port high connectivity configuration.

**Table 2: 64-Port High Connectivity ISL Connections**

Port	Switch #1	Switch #2	Switch #3	Switch #4	Switch #5	Switch #6
0	User Port					
1	User Port					
2	User Port					
3	User Port					
4	User Port					
5	User Port					
6	User Port					
7	User Port					
8	SW #1 Port 12	User Port	User Port	User Port	User Port	SW #5 Port 14
9	SW #1 Port 13	User Port	User Port	User Port	User Port	SW #5 Port 15
10	SW #1 Port 12	User Port	User Port	User Port	User Port	SW #4 Port 14
11	SW #2 Port 13	User Port	User Port	User Port	User Port	SW #4 Port 15
12	SW. #3 Port 12	SW. #1 Port 8	SW. #1 Port 10	SW. #1 Port 12	SW. #1 Port 14	SW. #3 Port 14
13	SW. #3 Port 13	SW. #1 Port 9	SW. #1 Port 11	SW. #1 Port 13	SW. #1 Port 15	SW. #3 Port 15
14	SW. #4 Port 12	SW. #6 Port 14	SW. #6 Port 12	SW. #6 Port 10	SW. #6 Port 8	SW. #2 Port 14
15	SW. #4 Port 13	SW. #6 Port 15	SW. #6 Port 13	SW. #6 Port 11	SW. #6 Port 9	SW. #2 Port 15

## 64-Port Fat Tree – High Bandwidth

The following figure is a logical representation of 12 16-port Compaq Fibre Channel switches configured as an Integrated 64-Port high bandwidth switch.

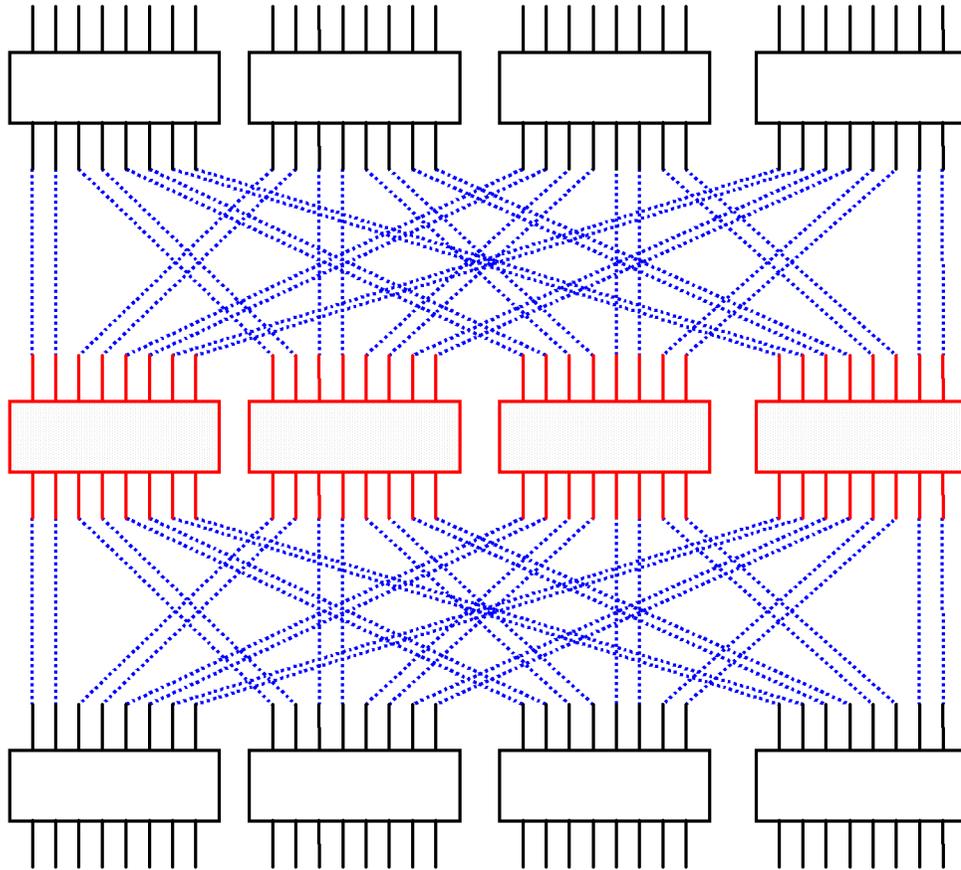


Figure 8. 64-Port High Bandwidth Configuration

**NOTE:** Figure 8 is a logical representation of the switches in this configuration. The following tables list the physical ISL cables with the source and destination port used for the 64-Port high bandwidth configuration.

**Table 3: 64-Port High Bandwidth ISL Connections**

Port	Switch #1	Switch #2	Switch #3	Switch #4	Switch #5	Switch #6
0	SW. #2 Port 8	User Port	User Port	User Port	User Port	SW. #11 Port 10
1	SW. #2 Port 9	User Port	User Port	User Port	User Port	SW. #11 Port 11
2	SW. #3 Port 8	User Port	User Port	User Port	User Port	SW. #10 Port 10
3	SW. #3 Port 9	User Port	User Port	User Port	User Port	SW. #10 Port 11
4	SW. #4 Port 8	User Port	User Port	User Port	User Port	SW. #9 Port 10
5	SW. #4 Port 9	User Port	User Port	User Port	User Port	SW. #9 Port 11
6	SW. #5 Port 8	User Port	User Port	User Port	User Port	SW. #8 Port 10
7	SW. #5 Port 9	User Port	User Port	User Port	User Port	SW. #8 Port 11
8	SW. #8 Port 8	SW. #1 Port 0	SW. #1 Port 2	SW. #1 Port 4	SW. #1 Port 6	SW. #5 Port 10
9	SW. #8 Port 9	SW. #1 Port 1	SW. #1 Port 3	SW. #1 Port 5	SW. #1 Port 7	SW. #5 Port 11
10	SW. #9 Port 8	SW. #6 Port 14	SW. #6 Port 12	SW. #6 Port 10	SW. #6 Port 8	SW. #4 Port 10
11	SW. #9 Port 9	SW. #6 Port 15	SW. #6 Port 13	SW. #6 Port 11	SW. #6 Port 9	SW. #4 Port 11
12	SW. #10 Port 8	SW. #7 Port 0	SW. #7 Port 2	SW. #7 Port 4	SW. #7 Port 6	SW. #3 Port 10
13	SW. #10 Port 9	SW. #7 Port 1	SW. #7 Port 3	SW. #7 Port 5	SW. #7 Port 7	SW. #3 Port 11
14	SW. #11 Port 8	SW. #12 Port 14	SW. #12 Port 12	SW. #12 Port 10	SW. #12 Port 8	SW. #2 Port 10
15	SW. #11 Port 9	SW. #12 Port 15	SW. #12 Port 13	SW. #12 Port 11	SW. #12 Port 9	SW. #2 Port 11

**Table 3: 64-Port High Bandwidth ISL Connections: Switches 7 to 12**

Port	Switch #7	Switch #8	Switch #9	Switch #10	Switch #11	Switch #12
0	SW. #2 Port 12	User Port	User Port	User Port	User Port	SW. #11 Port 14
1	SW. #2 Port 13	User Port	User Port	User Port	User Port	SW. #11 Port 15
2	SW. #3 Port 12	User Port	User Port	User Port	User Port	SW. #10 Port 14
3	SW. #3 Port 13	User Port	User Port	User Port	User Port	SW. #10 Port 15
4	SW. #4 Port 12	User Port	User Port	User Port	User Port	SW. #9 Port 14
5	SW. #4 Port 13	User Port	User Port	User Port	User Port	SW. #9 Port 15
6	SW. #5 Port 12	User Port	User Port	User Port	User Port	SW. #8 Port 14
7	SW. #5 Port 13	User Port	User Port	User Port	User Port	SW. #8 Port 15
8	SW. #8 Port 12	SW. #1 Port 8	SW. #1 Port 10	SW. #1 Port 12	SW. #1 Port 14	SW. #5 Port 14
9	SW. #8 Port 13	SW. #1 Port 9	SW. #1 Port 11	SW. #1 Port 13	SW. #1 Port 15	SW. #5 Port 15
10	SW. #9 Port 12	SW. #6 Port 6	SW. #6 Port 4	SW. #6 Port 2	SW. #6 Port 0	SW. #4 Port 14
11	SW. #9 Port 13	SW. #6 Port 7	SW. #6 Port 5	SW. #6 Port 3	SW. #6 Port 1	SW. #4 Port 15
12	SW. #10 Port 12	SW. #7 Port 8	SW. #7 Port 10	SW. #7 Port 12	SW. #7 Port 14	SW. #3 Port 14
13	SW. #10 Port 13	SW. #7 Port 9	SW. #7 Port 11	SW. #7 Port 13	SW. #7 Port 15	SW. #3 Port 15
14	SW. #11 Port 12	SW. #12 Port 6	SW. #12 Port 4	SW. #12 Port 2	SW. #12 Port 0	SW. #2 Port 14
15	SW. #11 Port 13	SW. #12 Port 7	SW. #12 Port 5	SW. #12 Port 3	SW. #12 Port 1	SW. #2 Port 15

## 96-Port Skinny Tree – High Connectivity

The following figure is a logical representation of 10 16-port Compaq Fibre Channel switches configured as an integrated 96-Port high connectivity switch.

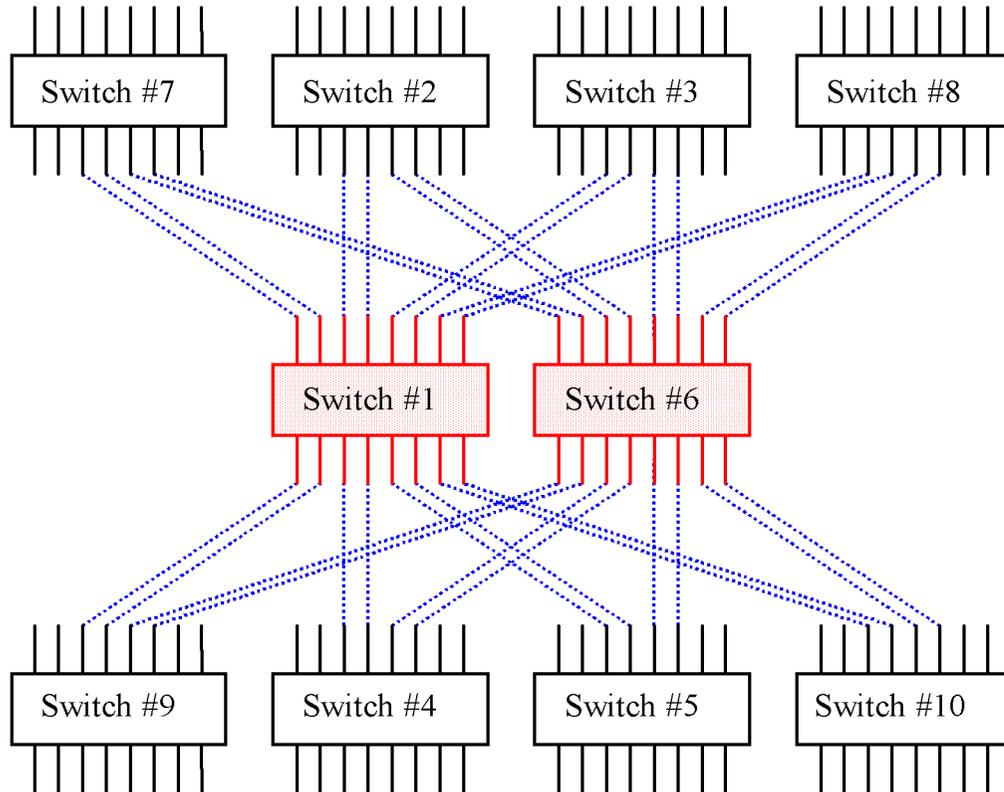


Figure 9. 96-Port High Connectivity Configuration

**NOTE:** Figure 9 is a logical representation of the switches in this configuration. The following tables list the physical ISL cables with the source and destination port used for the 96-Port high connectivity configuration.

**Table 4: 96-Port High Connectivity ISL Connections**

Port	Switch #7	Switch #8	Switch #9	Switch #10	Switch #11	Switch #12
0	SW #7 Port 12	User Port	User Port	User Port	User Port	SW #10 Port 14
1	SW #7 Port 13	User Port	User Port	User Port	User Port	SW #9 Port 15
2	SW #8 Port 12	User Port	User Port	User Port	User Port	SW #8 Port 14
3	SW #8 Port 13	User Port	User Port	User Port	User Port	SW #7 Port 15
4	SW. #9 Port 12	User Port	User Port	User Port	User Port	SW. #5 Port 14
5	SW. #9 Port 13	User Port	User Port	User Port	User Port	SW. #4 Port 15
6	SW. #10 Port 12	User Port	User Port	User Port	User Port	SW. #3 Port 14
7	SW. #10 Port 13	User Port	User Port	User Port	User Port	SW. #2 Port 15
8	SW #1 Port 12	User Port	User Port	User Port	User Port	SW #5 Port 14
9	SW #1 Port 13	User Port	User Port	User Port	User Port	SW #5 Port 15
10	SW #2 Port 12	User Port	User Port	User Port	User Port	SW #4 Port 14
11	SW #2 Port 13	User Port	User Port	User Port	User Port	SW #4 Port 15
12	SW. #3 Port 12	SW. #1 Port 8	SW. #1 Port 10	SW. #1 Port 12	SW. #1 Port 14	SW. #3 Port 14
13	SW. #3 Port 13	SW. #1 Port 9	SW. #1 Port 11	SW. #1 Port 13	SW. #1 Port 15	SW. #3 Port 15
14	SW. #4 Port 12	SW. #6 Port 14	SW. #6 Port 12	SW. #6 Port 10	SW. #6 Port 8	SW. #2 Port 14
15	SW. #4 Port 13	SW. #6 Port 15	SW. #6 Port 13	SW. #6 Port 11	SW. #6 Port 9	SW. #2 Port 15

**Table 4: 96-Port High Connectivity ISL Connections: Switches 7 to 10**

Port	Switch #7	Switch #8	Switch #9	Switch #10
0	User Port	User Port	User Port	User Port
1	User Port	User Port	User Port	User Port
2	User Port	User Port	User Port	User Port
3	User Port	User Port	User Port	User Port
4	User Port	User Port	User Port	User Port
5	User Port	User Port	User Port	User Port
6	User Port	User Port	User Port	User Port
7	User Port	User Port	User Port	User Port
8	User Port	User Port	User Port	User Port
9	User Port	User Port	User Port	User Port
10	User Port	User Port	User Port	User Port
11	User Port	User Port	User Port	User Port
12	SW. #1 Port 0	SW. #1 Port 2	SW. #1 Port 4	SW. #1 Port 6
13	SW. #1 Port 1	SW. #1 Port 3	SW. #1 Port 5	SW. #1 Port 7
14	SW. #6 Port 6	SW. #6 Port 4	SW. #6 Port 2	SW. #6 Port 0
15	SW. #6 Port 7	SW. #6 Port 5	SW. #6 Port 3	SW. #6 Port 1

## 128-Port Skinny Tree – High Connectivity

The following figure is a logical representation of 12 16-port Compaq Fibre Channel switches configured as an integrated 128-Port high connectivity switch.

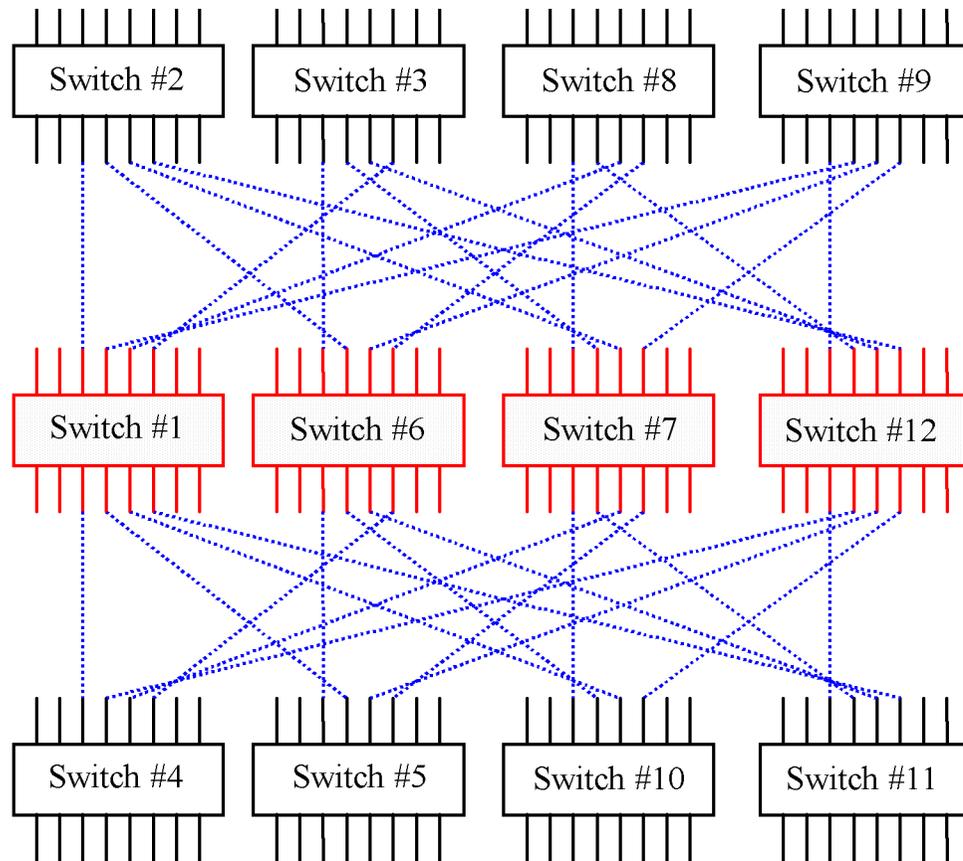


Figure 10. 128-Port High Connectivity Configuration

**NOTE:** Figure 10 is a logical representation of the switches in this configuration. The following tables list the physical ISL cables with the source and destination port used for the 128-Port high connectivity configuration.

**Table 5: 128-Port High Connectivity ISL Connections**

Port	Switch #1	Switch #2	Switch #3	Switch #4	Switch #5	Switch #6
0	User Port					
1	User Port					
2	User Port					
3	User Port					
4	User Port					
5	User Port					
6	User Port					
7	User Port					
8	SW. #2 Port 12	User Port	User Port	User Port	User Port	SW. #11 Port 13
9	SW. #3 Port 12	User Port	User Port	User Port	User Port	SW. #10 Port 13
10	SW. #4 Port 12	User Port	User Port	User Port	User Port	SW. #9 Port 13
11	SW. #5 Port 12	User Port	User Port	User Port	User Port	SW. #8 Port 13
12	SW. #8 Port 12	SW. #1 Port 8	SW. #1 Port 9	SW. #1 Port 10	SW. #1 Port 11	SW. #5 Port 13
13	SW. #9 Port 12	SW. #6 Port 15	SW. #6 Port 14	SW. #6 Port 13	SW. #6 Port 12	SW. #4 Port 13
14	SW. #10 Port 12	SW. #7 Port 8	SW. #7 Port 9	SW. #7 Port 10	SW. #7 Port 11	SW. #3 Port 13
15	SW. #11 Port 12	SW. #12 Port 15	SW. #12 Port 14	SW. #12 Port 13	SW. #12 Port 12	SW. #2 Port 13

**Table 5: 128-Port High Connectivity ISL Connections: Switches 7 to 12**

Port	Switch #7	Switch #8	Switch #9	Switch #10	Switch #11	Switch #12
0	User Port	User Port	User Port	User Port	User Port	User Port
1	User Port	User Port	User Port	User Port	User Port	User Port
2	User Port	User Port	User Port	User Port	User Port	User Port
3	User Port	User Port	User Port	User Port	User Port	User Port
4	User Port	User Port	User Port	User Port	User Port	User Port
5	User Port	User Port	User Port	User Port	User Port	User Port
6	User Port	User Port	User Port	User Port	User Port	User Port
7	User Port	User Port	User Port	User Port	User Port	User Port
8	SW. #2 Port 14	User Port	User Port	User Port	User Port	SW. #11 Port 15
9	SW. #3 Port 14	User Port	User Port	User Port	User Port	SW. #10 Port 15
10	SW. #4 Port 14	User Port	User Port	User Port	User Port	SW. #9 Port 15
11	SW. #5 Port 14	User Port	User Port	User Port	User Port	SW. #8 Port 15
12	SW. #8 Port 14	SW. #1 Port 12	SW. #1 Port 13	SW. #1 Port 14	SW. #1 Port 15	SW. #5 Port 15
13	SW. #9 Port 14	SW. #6 Port 11	SW. #6 Port 10	SW. #6 Port 9	SW. #6 Port 8	SW. #4 Port 15
14	SW. #10 Port 14	SW. #7 Port 12	SW. #7 Port 13	SW. #7 Port 14	SW. #7 Port 15	SW. #3 Port 15
15	SW. #11 Port 14	SW. #12 Port 11	SW. #12 Port 10	SW. #12 Port 9	SW. #12 Port 8	SW. #2 Port 15