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# Understanding Compaq StorageWorks RAID Array 4000 and Infrastructure Cabling

**Abstract:** Compaq StorageWorks RAID Array 4000<sup>1</sup> (RA4000) storage solutions shatter distance, connectivity, capacity, and bandwidth limitations of small computer systems interface (SCSI) technology. RA4000 allows highly scalable, high-performance storage solutions for the most demanding applications. While SCSI technology continues to satisfy the needs of many applications, inherent input/output (I/O) and physical limitations prevent SCSI technology from satisfying all of the expanding needs of enterprise storage. Compaq believes that the RA4000 is the best interconnect technology choice for future storage solutions and is committed to delivering enterprise storage solutions based on this technology.

This paper describes Fibre Channel transmission and the cabling and components used to assemble the RA4000 system. It also describes how and when infrastructure cabling might be used.

If plans for a Fibre Channel storage solution include using infrastructure cabling, a company that provides installation and testing services can be helpful, even necessary, to determine appropriate cabling to meet data transmission rate and distance requirements. See *Acknowledgments and References* later in this document.

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**Note:** Not all Fibre Channel configurations require connection to infrastructure cabling. It is common to have all system components located near each other, eliminating the need for infrastructure cabling. This paper includes examples of RA4000 configurations with and without infrastructure cabling.

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For more information on Fibre Channel technology, refer to the Compaq website:

[www.compaq.com/products/servers/storage/fibre.html](http://www.compaq.com/products/servers/storage/fibre.html)

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<sup>1</sup> RA4000 was known as the Fibre Channel Storage System.

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## Understanding Fibre Channel Transmission

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**Note:** This paper includes the terms *fibre* and *fiber*. Fibre is the international spelling that refers to the Fibre Channel Standards that include both optical and copper media. Fiber refers to the optical media used to implement Fibre Channel.

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Fibre Channel uses lasers<sup>2</sup> to achieve gigabit data transmission rates. The ones and zeros used to convey information are generated by turning a laser on and off. The receiver detects these bursts of light and converts them to electrical signals.

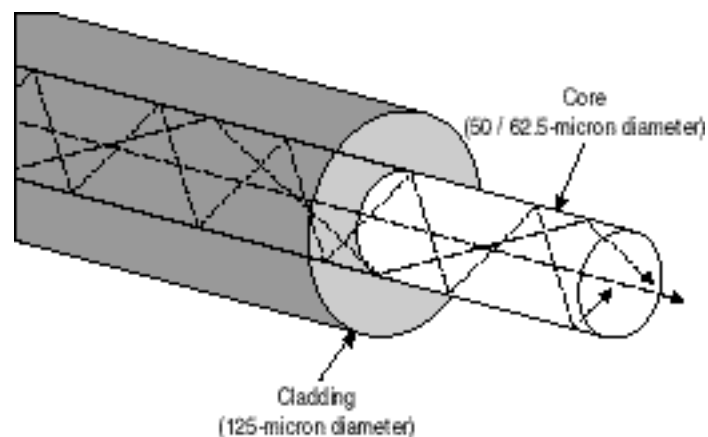
Lasers used in Fibre Channel transmit light in two wavelength ranges:

- Shortwave, 770 to 860 nanometers
- Longwave, 1,270 to 1,355 nanometers

Optical fiber cable is the medium used in RA4000 solutions. Characteristics of optical fiber cable are:

- High bandwidth.
- Transmits data over long distances.
- Increased data transmission reliability.
- Immunity to electrical noise.
- Does not radiate energy.

Optical fiber cable is categorized as either multi-mode<sup>3</sup> or single-mode. In Figure 1, the diameter of a multi-mode fiber is large enough to allow multiple streams of light to travel on different paths from the transmitter to the receiver. Shortwave lasers are used with multi-mode fiber to transmit data up to 500 meters.



**Figure 1. Multi-mode fiber cable**

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<sup>2</sup> Laser technology uses fiber optic media only.

<sup>3</sup> Mode means path.

In Figure 2, the small diameter of a single-mode fiber allows one coherent stream of light to travel along a single path. Longwave lasers are used with single-mode fiber to transmit data up to 10 kilometers.

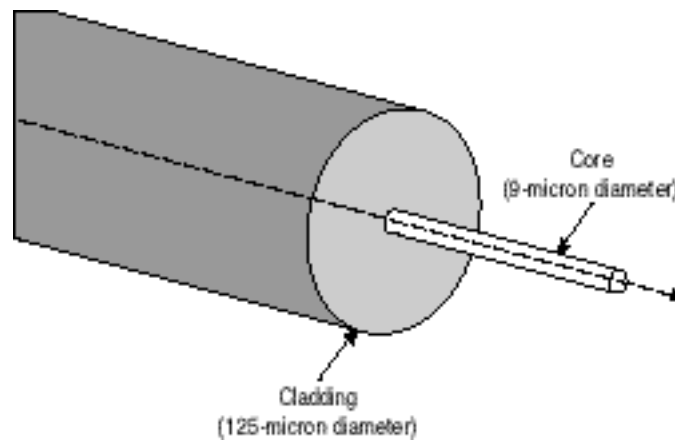


Figure 2. Single-mode fiber cable

## Understanding Fiber Types

Types of fibre channel media<sup>4</sup> include:

- 62.5-micron multi-mode.
- 50-micron multi-mode.
- 9-micron single-mode.

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<sup>4</sup> The fiber types are distinguishable by their data transmission rates and distance capabilities.

## Distance Limitations

Two factors that can limit the distance between the components are:

1. The data transmission rate—as shown in Table 1, the distance between the components of each fiber type tends to decrease as the data transmission rate increases.
2. The degree of attenuation—attenuation is the reduction of the signal strength during transmission from point to point. In this case, it is the light passing through the optic media. The number of connectors and splices used to connect components affects the distance that can exist between components.

**Table 1. Data transmission rates and distance capabilities of fiber types**

Transmission Rate	Supported by Compaq	62.5-micron	50-micron	9-micron
100 MB/s <sup>5</sup>	Yes	300 m	500 m	10 km
200 MB/s	Future <sup>6</sup>	150 m	300 m	2 km
400 MB/s	Future	90 m	150 m	2 km

Formulas used to calculate the distance limitations are based on the data transmission rates and the degree of attenuation. A company that provides fiber products and installation and testing services can help determine distance capabilities and limitations for a particular installation. See Acknowledgements and References later in this document.

## Connection Components

To build a storage system that uses fibre channel technology, it is necessary to understand the use and function of, hubs, gigabit interface converters (GBICs), and fibre channel cables and connectors.

- Hubs allow of different GBIC types to be mixed so there can be different cable types within a fibre channel topology. Hubs use port bypass circuitry to keep a fibre channel loop topology intact.
- GBICs convert electrical signals to optical signals and optical signals to electrical signals at the point where fiber cables connect to copper-wired components (hubs, controller cards, and host adapters).
- Fibre channel cables and connectors join system components and connect to infrastructure cabling.

<sup>5</sup> Megabytes per second

<sup>6</sup> A 200 MB/s transmission rate may be passed over in favor of a 400 MB/s transmission rate.

## Hubs

Hubs provide the ability to use different fibre channel cables in the same loop to accommodate different types of infrastructure cabling. Figure 3 shows an example of a 62.5-micron multi-mode cable, a 50-micron multi-mode cable, and a 9-micron single-mode cable used in the same loop. The hub's ability to detect and bypass non-operational ports keeps the loop intact.

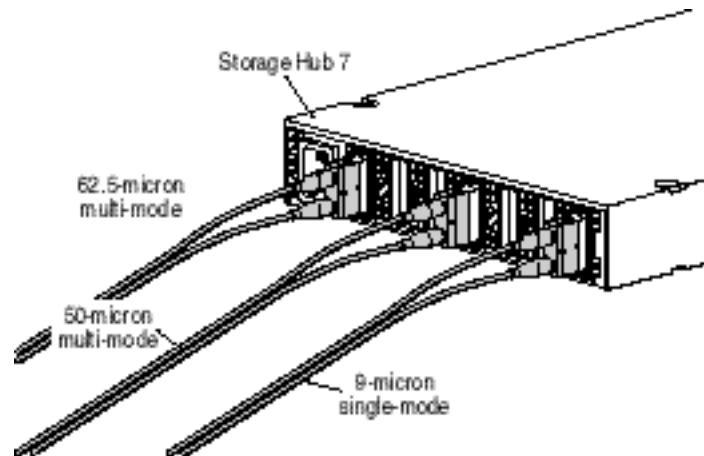


Figure 3. Using a hub to intermix fiber types

## Gigabit Interface Converters

These industry-standard connection devices hot plug into all Fibre Channel System components (host controllers, cables, hubs, and arrays). A shortwave GBIC (GBIC-SW) must be used with a multi-mode fibre channel cable and a long wave GBIC (GBIC-LW) must be used with a single-mode fibre channel cable.

A GBIC:

- Converts electrical signals into optical signals.
- Converts optical signals into electrical signals.
- Provides a transmission rate of 100 MB/s in each direction.

A GBIC-SW provides a transmission distance between components of up to 500 meters using 50-micron, multi-mode fiber optic cable. A GBIC-LW provides a transmission distance between components of up to 10 kilometers using 9-micron, single-mode fiber optic cable.

A label describes the GBIC and distinguishes it as shortwave or long wave. The description may spell out a GBIC's characteristics or it may use the Fibre Channel Standard convention for labeling. The labeling convention is SPEED-MEDIA-TRANSMITTER-DISTANCE.

An example of a GBIC label is 100-M5-SN-I. Use Table 2 to decode the example label as follows:

- 100 means a bandwidth of 100 MB/s.
- M5 means 50-micron multi-mode cable.
- SN means shortwave laser without OFC.
- I means intermediate distance.

**Table 2. Fibre Channel Standard convention for GBIC labeling**

Speed	100 = 100 MB/s*	200 = 200 MB/s	400 = 400 MB/s
Media	SM = 9-micron single-mode	M5 = 50-micron multi-mode	M6** = 62.5-micron multi-mode
Transmitter	LL = long wave laser (1300 nanometers)	SL = shortwave laser with OFC (850 nanometers)	SN = shortwave laser without OFC (850 nanometers)
Distance	L = long distance (2 m to 10 km)	I = Intermediate distance (2 m to 500 m)	S = short distance (2 m to 300 m)
* 1063 MBd is the data rate measured in megabaud and is equivalent to 106.3 MB/s, or 100 MB/s nominally.			
** A cable labeled M6 can be used with an M5 GBIC.			
*** Compaq only supports shortwave lasers without open fiber control (OFC), the SN version. OFC limits the amount of light transmitted when the fiber connection is broken to prevent eye injury. Improvements in laser control technology have eliminated the need for OFC.			

## Fibre Channel Cables and Connectors

Typically, fibre channel cables are a pair of fibers with connectors on each end. The fibers in a fibre channel cable cross so that the input at one end of the fibre channel cable becomes the output at the other end. The connectors are keyed to ensure that the connections are properly oriented.

Compaq supplies 50-micron, multi-mode fibre channel cables in fixed lengths of 2 meters, 5 meters, 15 meters, 30 meters, and 50 meters. Compaq RA4000 storage system components ship standard with 50-micron, multi-mode fibre channel cables. Support for 62.5-micron, multi-mode and 9-micron, single-mode fibre channel cables is also available.

Fibre channel cables that connect to infrastructure cabling must match the fiber type of the infrastructure cabling. For example, if 62.5-micron, multi-mode infrastructure cabling connects to a wall outlet, the cabling that runs from the server to that wall outlet must be 62.5-micron, multi-mode cable.

Connecting 50-micron fibre channel cable to 62.5-micron fibre channel cable can cause severe degradation of the optical signal. This can result in marginal operation or an unreliable connection.

Cable assembly suppliers can provide custom combinations of cable length, connector type, and fiber type to mate with infrastructure cabling. See Acknowledgments and References later in this document for suppliers.

Fibre channel cable types are labeled at one-meter intervals on the cable. A fibre channel cable labeled “50/125” indicates a 50 micron inner core with 125 micron outer cladding. Table 3 identifies the color coding for fibre channel cables.

**Table 3. Standard fibre channel cable color codes**

Size	Color
62.5 micron	Slate gray or orange
50 micron	Orange
9 micron	Yellow

Compaq RA4000 system components interconnect using 50-micron and 62.5-micron multi-mode cables and 9-micron single-mode cables. However, Compaq only provides 50-micron multi-mode cables with the product. Customers can acquire the other cable types from Compaq and other sources. Refer to Acknowledgements and References later in this document.

## Interconnecting System Components

This section discusses interconnecting primary storage system components using the RA4000.

### Overview of System Components

The RA4000 uses the components described in Table 4.

**Table 4. Compaq StorageWorks RAID Array 4000 components**

Component	Description
RA4000	An external storage cabinet that houses the RA4000 Controller and up to twelve 1-inch or eight 1.6-inch SCSI disk drives (Wide-Ultra SCSI-3, Fast-Wide SCSI-2, or Fast SCSI-2).
RA4000 Controller	An intelligent fibre channel-to-SCSI array controller with 64 MB cache.
Optional RA4000 Redundant Controller	A standby controller that takes over in the event a component or connection fails in a redundant configuration that provides no single point of failure. The redundant controller is an RA4000 Controller with redundancy support firmware.
Compaq StorageWorks Fibre Channel Storage Hub 7	Supports up to 7 devices on a fibre channel arbitrated loop.
Compaq StorageWorks Fibre Channel Storage Hub 12	Supports up to 12 devices on a fibre channel arbitrated loop.
Compaq StorageWorks Fibre Channel Host Adapter/E	An EISA-to-Fibre Channel Host Adapter.
Compaq StorageWorks Fibre Channel Host Adapter/P	A PCI-to-Fibre Channel Host Adapter.
GBIC-SW	Converts optical signals (770 to 860 nanometers) into electrical signals and electrical signals into optical signals. Allows point-to-point connections for distances up to 500 m.
GBIC-LW	Converts optical signals (1,270 to 1,355 nanometers) into electrical signals and electrical signals into optical signals. Allows point-to-point connections for distances up to 10 km.
Multi-mode Cable	2-m, 5-m, 15-m, 30-m, or 50-m 50-micron fiber optic cable. All cables are available as separate options. For 62.5-micron fiber optic cable, refer to Acknowledgements and References later in this document.
Single-mode Cable	Refer to Acknowledgements and References later in this document.



## RAID Array 4000 Configurations

This section discusses possible RA4000 configurations without infrastructure cabling. For simplicity, only a few possible configurations will be discussed. For more information on fibre channel technology, refer to the Compaq website:

[www.compaq.com/products/storageworks/](http://www.compaq.com/products/storageworks/)

### Single-Server Environments

In single-server environments, it is possible to connect the server directly to the RA4000.

In many cases, the server, the hub, and the storage arrays are located close to each other, making interconnections easy to configure without using infrastructure cabling.

In Figure 4, the Fibre Channel Host Adapter connects to a Storage Hub 7. The Storage Hub 7 connects to three RA4000s. GBICs are installed at all fiber interconnections. There is no redundancy to protect the data in this configuration should a component fail.

Using custom-length, 50-micron fiber, interconnect distances between components can be up to 500 meters. Therefore, RA4000s can be located up to 1 kilometer from the Fibre Channel Host Adapter.

Using custom-length, 9-micron fiber, interconnect distances between components can be up to 10 kilometers. Therefore, RA4000s can be located up to 20 kilometers from the Fibre Channel Host Adapter.

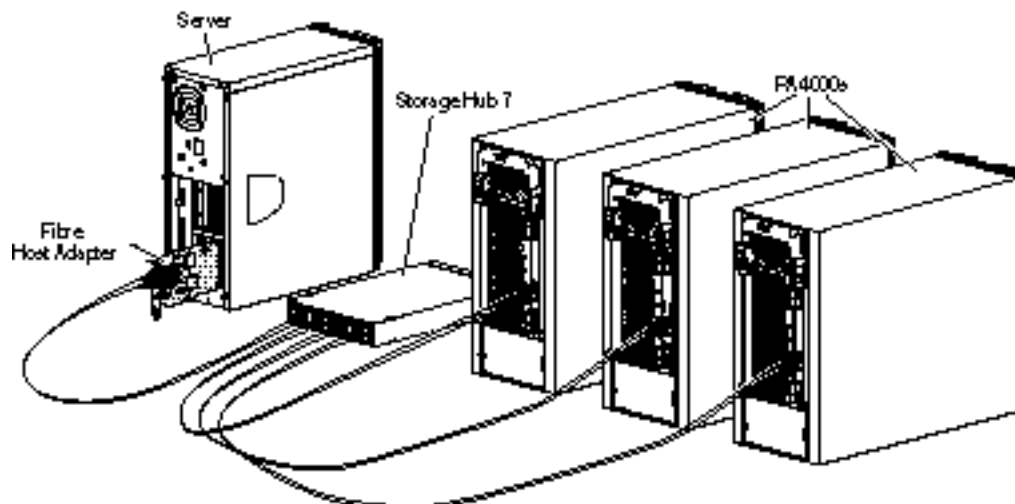


Figure 4. Single server and single controller RA4000s

The RA4000 brings no single point of failure (NSPOF) functionality to workgroup and departmental servers with optional redundant array controllers and failover software. In a redundant configuration, if the active controller or other component fails or becomes inoperative, the standby controller will take over, notify the system administrator of the problem, and maintain operation of the storage subsystem.

Figure 5 shows the minimum hardware requirements for a single server and single RA4000 with NSPOF.

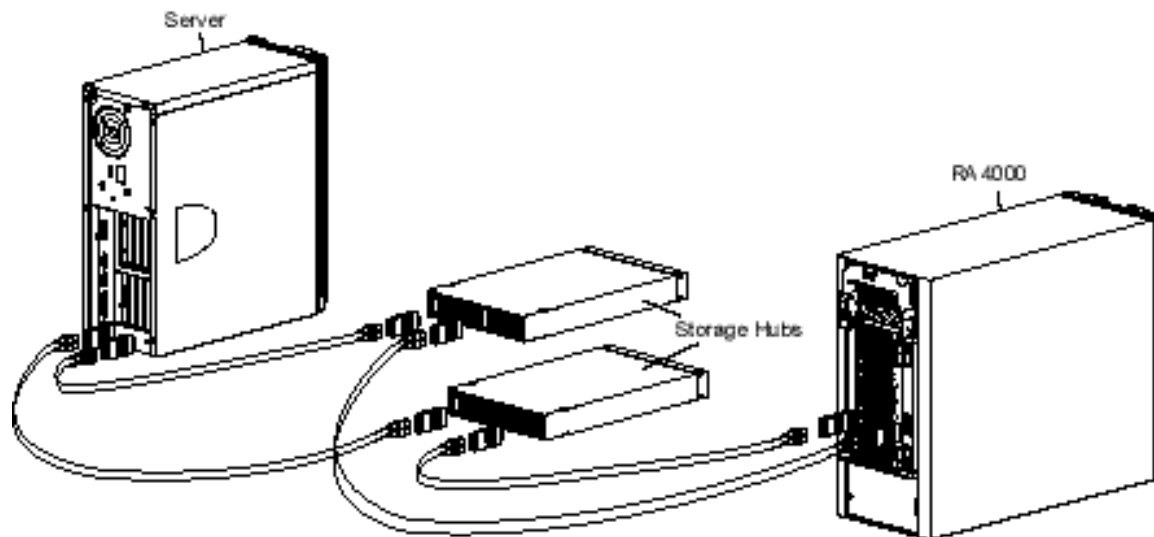


Figure 5. Single server and redundant controller configuration

### Clustered Server Environments

Figure 6 shows a clustered configuration without NSPOF.

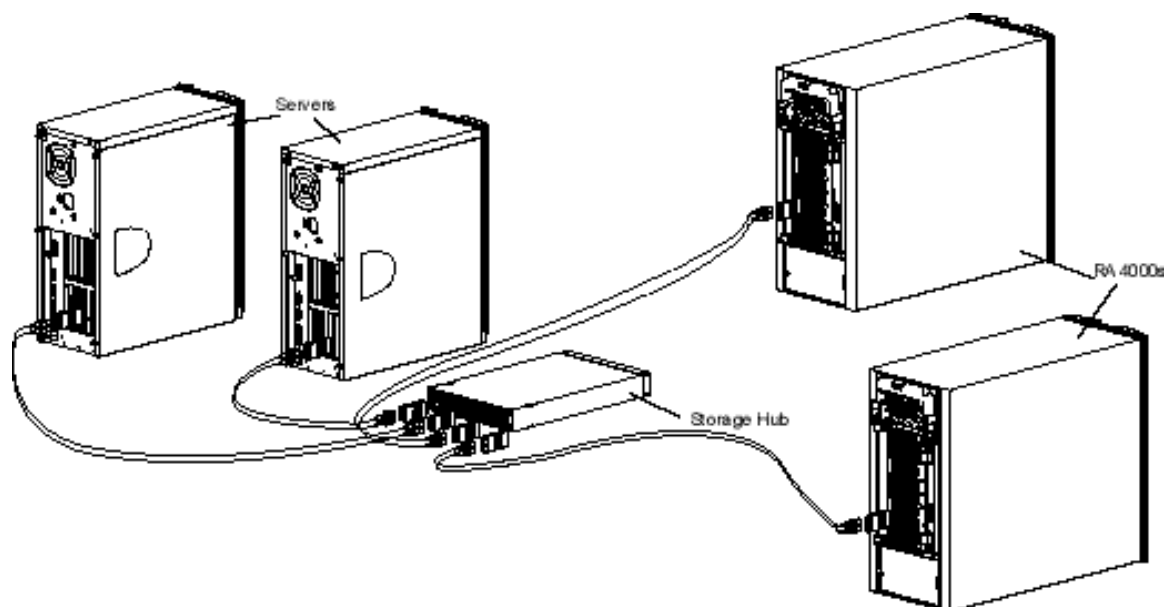
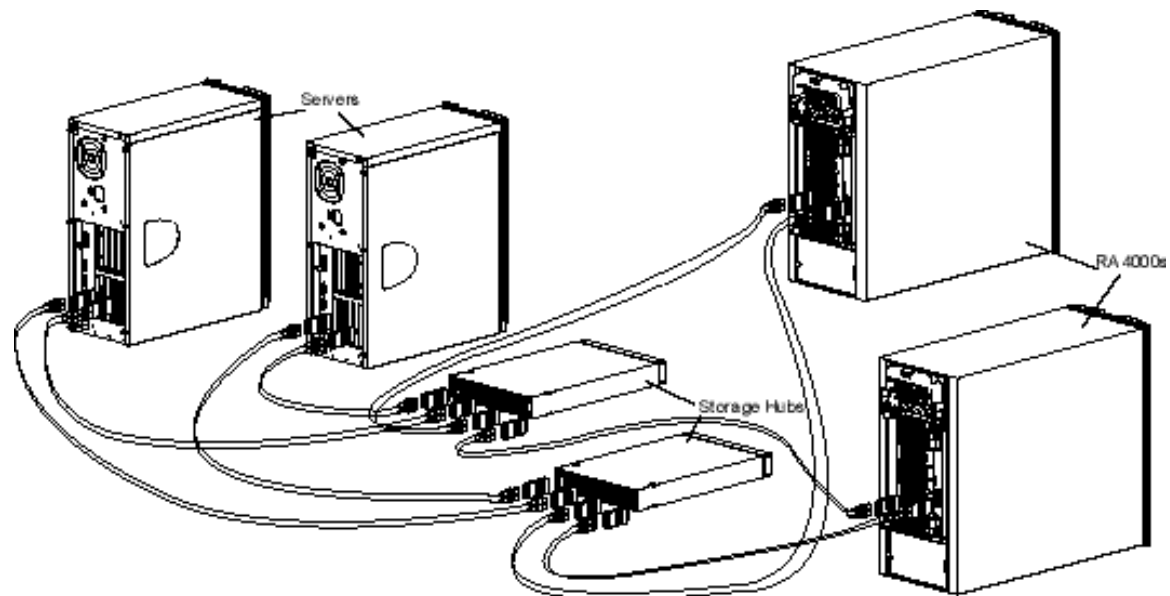


Figure 6. Single controllers in a clustered configuration

Figure 7 shows a clustered server environment with NSPOF.



**Figure 7. Redundant controllers in a clustered configuration**

Since many enterprises' storage components are located across greater distances, the servers are connected through single-mode cabling.

## Using Infrastructure Cabling

Infrastructure cabling (or cable plant) refers to the complete cabling system within a building or buildings. This section discusses of infrastructure cabling and includes a scenario in which an RA4000 uses infrastructure cabling to connect across multiple floors. This example should help answer the questions:

- Is the existing infrastructure cabling useable?
- Does new infrastructure cabling need to be installed?
- If new infrastructure cabling is needed, what type should be installed?

## Typical Fiber Infrastructure Cabling Scheme

Figure 8 shows a fiber infrastructure-cabling scheme across three floors. A fibre channel cable (or a patch cable) connects servers to work area outlets. Horizontal fiber cable connects work area outlets to telecommunications closets. In the telecommunications closets, horizontal and backbone cables interconnect through fibre channel patch panels. The fiber backbone cable connects telecommunications closets to the main distribution center.

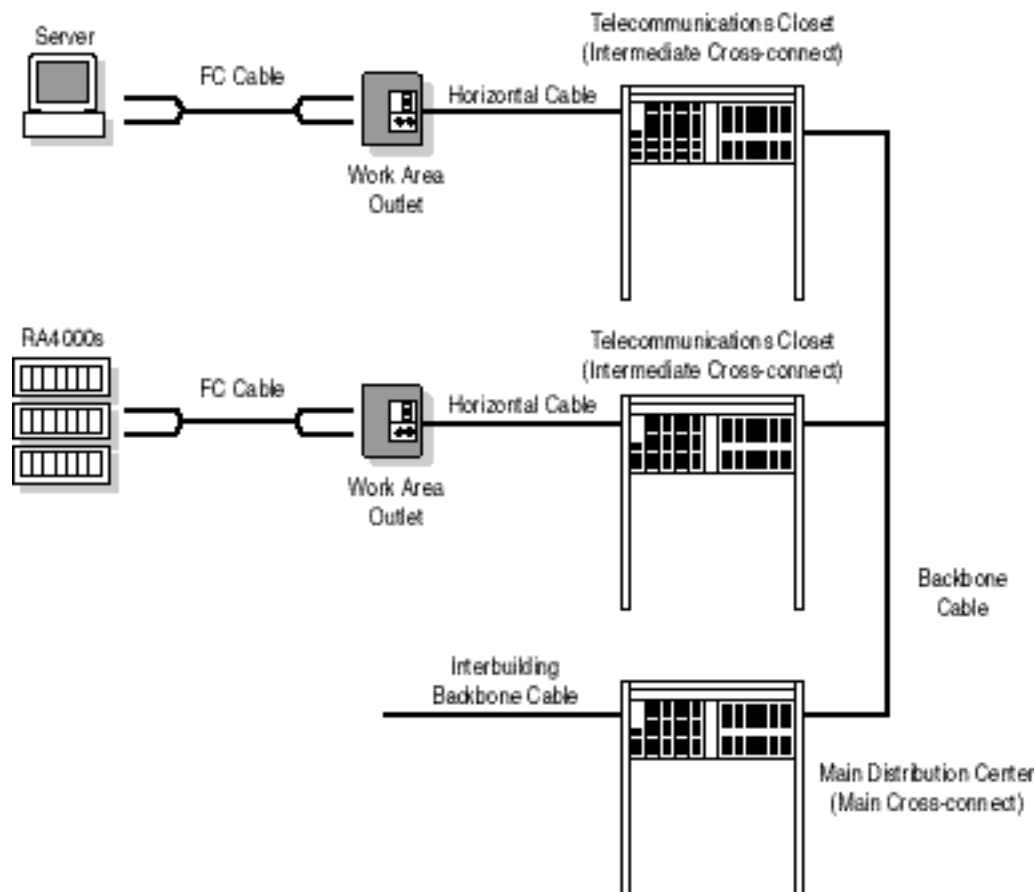


Figure 8. Infrastructure cabling across three floors

## Compaq StorageWorks RAID Array 4000 Using Infrastructure Cabling

Consider the scenario in which the server is located several floors away from its storage:

A server is located in the telecommunications closet on the  $n^{\text{th}}$  floor of a building and will connect to a hub and storage arrays located in the basement. Connecting the server to the hub requires infrastructure cabling. What type of infrastructure cabling will work?

To select an appropriate fiber type, measure the length of the backbone cable and determine the data transmission rate. Remember, data transmission rates and attenuation limit distance capability.

**Table 5. Appropriate fibre channel cable type at 100 MB/s**

Distance between components	Use
$\geq 0$ m and $\leq 300$ m	➡ 62.5, 50, or 9 micron fiber
$\geq 200$ m and $\leq 500$ m	➡ 50 or 9 micron fiber
$\geq 500$ m and $\leq 10$ km	➡ 9 micron fiber

### Using Existing Cabling or Installing New Cabling

If you determine that 62.5 micron fiber will support your configuration and you have 62.5 micron installed in the building, you can use the existing fiber.

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**Note:** Compaq does not require that the bandwidth of all cables be measured. Measurement of existing fiber only needs to be done if the bandwidth value is unknown.

The manufacturer measures the bandwidth of new fiber. Therefore, a bandwidth measurement is not necessary for new fiber for which the bandwidth is already known.

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Be sure to consider any plans for expanding the system and using increased data transmission rates. To support expansion and increased data transmission rates, 50 micron fiber or 9 micron fiber may be required.

If you have no fiber cable installed in the building, Compaq recommends that you use 50 micron fiber. The primary standard for fibre channel connections is 50 micron fiber which allows flexibility for system expansion and supports faster data transmission rates across greater distances.

If you have no fiber installed, or if 62.5 micron does not satisfy distance requirements, the choice between 50 micron and 9 micron fiber depends on current and future configuration requirements and the use of faster data transmission rates.

## Testing

Testing ensures proper operation and reduces the error rate.

The power generated by the transmitter and the sensitivity of the receiver determine the amount of power available. This amount must be greater than the sum of any power penalties and the attenuation between the optical transmitter and receiver.

Attenuation will always occur in the fiber, connectors, and splices. A variety of factors can cause excessive attenuation, and testing detects excessive attenuation between components.

For example, a splice will always cause some amount of attenuation, but a poorly joined splice may cause attenuation that exceeds expectations. Bad connections can be detected and repaired during testing.

Individuals experienced in testing and installing fiber optic infrastructure cabling should test cabling for the link insertion loss after installation. Testing existing infrastructure cabling can be difficult because portable bandwidth test equipment may not be available. For more information, see *Acknowledgments and References* later in this document.

## Test Specifications

Multi-mode cables should be tested such that the total link insertion loss from the transmitter to the receiver is no greater than 6 dB minus any associated power penalties. EIA/TIA-526-14, Method B can be used for insertion loss testing.

The modal bandwidth requirement for 62.5-micron multi-mode cables is 160 MHz·km at 850 nm. The fiber must comply with the appropriate Fiber Optic Test Procedure (FOTP-30, FOTP-51, FOTP-54) for testing multi-mode cable bandwidth as supplied by the fiber manufacturer. The length (62.5/125 optical cable) is limited by the bandwidth of the cable. A larger core size cable results in higher modal dispersion, producing a lower bandwidth, and limits the length to shorter distances between components.

The modal bandwidth requirement for 50-micron multi-mode cables is 500 MHz·km at 850 nm as tested by the fiber manufacturer. This higher modal bandwidth results in longer achievable distances between components, compared to 62.5 micron multi-mode cables, for a given data rate.

## Handling Fiber and Fiber Connectors

Observe the following guidelines for handling fiber and fiber connectors:

- Protect optical components from heat, contaminants, abrasion, excessive differential or lateral movement, and mechanical hazards.
- Avoid kinking or small-bend radii of the fiber. The rule of thumb is that the bend radius should be greater than 10 times the outside diameter of the cable. For Compaq-supplied fibre channel cables, the bend radius is 30 millimeters, or 1.25 inches.
- Do not place heavy objects or other heavier cables on top of fiber cable. These objects can deform the fiber.

All of these factors can reduce the amount of light passing through a cable or connection and can degrade performance.

GBICs and fibre channel cables ship with dust caps installed and these caps should remain installed until an optical connection is made. Reinstall the dust caps whenever cables and connectors are detached.

Compaq products ship with instructions for making proper connections. Clean a connection any time it may have been exposed to dust or when there is any doubt about its cleanliness.

## Acknowledgments and References

Compaq would like to thank Alcoa Fujikura, Ltd. ([www.alcoa.com](http://www.alcoa.com)) and Siecor ([www.siecor.com](http://www.siecor.com)) for their contributions to this paper. Both companies provide fiber products and installation and testing services.

For Compaq supplied fibre channel products refer to the following two sites:

- [www.compaq.com](http://www.compaq.com)
- [www.compaq.com/products/storageworks/](http://www.compaq.com/products/storageworks/)

Other companies that provide fiber products and installation and testing services are listed in the Fibre Channel Community Web pages:

[www.fcloop.org/vlist/default.asp](http://www.fcloop.org/vlist/default.asp)