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Compaq Computer Corporation

Contents

Compaq RAID Array 4000 Overview

Abstract: The Compaq StorageWorks RAID Array 4000 (RA4000), formerly the Fibre Channel Storage System, is an external storage solution incorporating Fibre Channel interconnect technology. This solution overcomes inherent limitations of small computer systems interface (SCSI) interconnect technology. Fibre Channel interconnect technology is designed to satisfy the requirements of such enterprise applications as databases, data marts, email, groupware, Web servers, and file and print for large storage capacity and scalable input/output (I/O) performance.

The architecture of this Fibre Channel storage solution enables administrators to simultaneously achieve multiple goals:

- To provide hardware redundancy and failover capabilities with no single point of failure (NSPOF).
- To build a scalable external storage solution for high capacity or high growth applications by:
  - Scaling a single I/O slot to more than 3.2 TB.
  - Scaling an 8-PCI-slot server to more than 25.6 TB.
- To scale cache and processing power for increased I/O performance.
- To conserve I/O slots for connecting other types of I/O devices.

This technology brief explains the hardware components, hardware architecture, firmware functionality, software support, and performance expectations for the RA4000.

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Compaq RAID Array 4000 Overview
Technology Brief prepared by ECG Technology Communications Group

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Introduction

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

Applications central to enterprise operations demand remarkable storage capacity and scalable performance. Data marts, for example, may grow by as much as 400 percent per year. Email data and Lotus Notes data typically double each year. Databases and consolidated print and file applications also demand increasing storage capacity. With its inherent I/O and physical limitations, SCSI technology cannot support the scalability of storage capacity and I/O performance required by such applications.

The expanding need for enterprise storage capacity and performance demands new storage solutions. After extensively studying possible alternatives, Compaq has determined that Fibre Channel is the best interconnect technology to propel growth of enterprise storage. As a result, Compaq actively participates in industry standardization efforts for Fibre Channel interconnect technology and is continuing to develop products incorporating that technology.

The RA4000 is a primary storage solution incorporating Fibre Channel technology. The Fibre Channel architecture of this solution enables administrators to scale the storage capacity supported by a single, 8 PCI-slot server from gigabytes to more than 25.6 TB, while simultaneously scaling cache, processing power, and throughput of their storage subsystem.

The RA4000 is an external array storage system which means the array controller is housed in the hard disk drive (HDD) instead of the server. This design enables clustering and NSPOF configurations that allows the enterprise to reduce its planned and unplanned downtime.

Unplanned system downtime, which usually is caused by component failure, can be significantly reduced by using RAID and redundant components. Planned downtime, such as planned maintenance or system expansion, also can be reduced with the RA4000 solution.

Features of the RA4000 include:

- Online capacity expansion
- Hot growth
- Hot add (Novell)
- PCI hot-plug support
- The connectivity benefits of Fibre Channel technology[1]

The RA4000 solution provides enterprises with increased availability, scalability in both performance and capacity, and a tight integration with ProLiant servers. This leap in capacity, scalability, and availability results from innovations to proven Compaq hardware and software products and from total storage system integration. The RA4000 targets computing environments that require large, rapidly growing storage capacity and scalable I/O performance.

This technology brief will explain the hardware components, hardware architecture, firmware functionality, software support, and performance expectations for the RA4000.

[1] It is easier to add storage in rack configurations.

Hardware Technology

The RA4000 consists of 11 hardware components that can be interconnected to form a Fibre Channel Arbitrated Loop (FC-AL) topology:

- Compaq StorageWorks RAID Array 4000
- Compaq StorageWorks RAID Array 4000 Controller
- Compaq StorageWorks RAID Array 4000 Redundant Controller[2]
- Compaq StorageWorks Fibre Channel Host Adapter/E
- Compaq StorageWorks Fibre Channel Host Adapter/P
- Compaq StorageWorks Fibre Channel Storage Hub 7
- Compaq StorageWorks Fibre Channel Storage Hub 12
- Short wave gigabit interface converters
- Long wave gigabit interface converters
- Multi-Mode Fibre Channel Cables
- Single-Mode Fibre Channel Cables

StorageWorks RAID Array 4000

This section describes the function of each hardware component and then explains the hardware architecture and Fibre Channel topology used in the RA4000.

An RA4000 is an external drive enclosure containing:

- A high-performance RA4000 Controller.
- An optional RA4000 Redundant Controller.
- A hot-pluggable fan assembly.
- Optional redundant hot-pluggable power supplies.

The RA4000 is available in a tower or a 4U rack form factor and supports hot-pluggable drives.

The RA4000 enhances the availability of data through redundant controllers that can be deployed in an NSPOF storage system.

[2] The redundant controller is an RA4000 Controller with redundancy support firmware.

A single RA4000 accommodates up to eight 1.6-inch or twelve 1-inch Wide-Ultra SCSI-3, Fast-Wide SCSI-2 or Fast SCSI-2 drives. As Table 1 shows, a single, fully populated RA4000 can provide a total capacity of up to 291.2 GB using eight hard disk drives. For installations in which improved performance (spindle density for example) is more important than maximum capacity, 12 hard drives placed in an RA4000 can provide up to 218.4 GB of capacity.

Table 1. Storage capacity of a single Compaq StorageWorks RAID Array 4000

Maximum Number of Drives	Drive Size (inches)	Native Capacity per Drive (gigabytes)	Maximum Total Capacity (gigabytes)		
			RAID 0	RAID 1	RAID 4 or 5
8	1.6	36.4	291.2	145.6	254.8
8	1.6	18.2	145.6	72.8	127.4
8	1.6	9.1	72.8	36.4	63.7
12	1.0	18.2	218.4	109.2	200.2
12	1.0	9.1	109.2	54.6	100.1
12	1.0	4.3	51.6	25.8	47.3

StorageWorks RAID Array 4000 Controllers

The RA4000 Controller is an intelligent Fibre Channel-to-SCSI array[3] controller integrated into the RA4000 solution. The controller is based on the Compaq SMART-2 architecture and has two Wide-Ultra SCSI-3 channels. Each channel can transfer data at 40 megabytes per second (MB/s) for a total of 80 MB/s possible internal bandwidth. The array controller-to-host interface is Fibre Channel for high-speed connection to the server. The Fibre Channel interface can transfer data to the server at burst rates of 100 MB/s.

The RA4000 Controller:

- Supports RAID[4] 0, 0+1, 1, 4, and 5.
- Supports multiple logical drives and online capacity expansion within the array.
- Features sixth-generation Compaq RAID technology and components.
- Can have a total of 64 MB of usable cache (16 MB read and 48 MB user-selectable read/write). The cache is scalable up to 5.6 GB in an 8-slot, single server environment.

The RA4000 Redundant Controller is the same controller as the standard RA4000 controller with redundancy support firmware embedded that adds higher availability not found previously in Compaq storage systems. The RA4000 Redundant Controller fully supports Compaq Insight Manager, Pre-Failure Warranty, and Fibre Channel Host Adapter failover.

The RA4000 Controller and RA4000 Redundant Controller supports Wide-Ultra SCSI-3, Fast-Wide SCSI-2, or Fast SCSI-2 drives. Use of SCSI technology inside the RA4000 allows customers to use existing SCSI disk drives. Since hard disk drives are the most costly part of a storage system, this compatibility can reduce the cost of implementing an RA4000.

[3] An array is a set of disk drives that are physically grouped together and can be subdivided into logical drives consisting of one or more disks in the set.
[4] Redundant Array of Independent Disks. RAID levels are methods that improve array performance and provide for protection of the data on disks.

Hot-Swapping Disk Drives

The RA4000 Controller supports individual failed disk drives to be removed from an RA4000 and replaced them while the array is active. After the new drive is installed, the Compaq Automatic Data Recovery software automatically rebuilds data on the new drive without administrator intervention.

Online Capacity Expansion

The RA4000 Controller supports adding disk drives to an RA4000 and redistributing the data across the drives in the array while the array is active. Note, however, that to add an additional RA4000 to the overall storage system, reboot the server.

Array Accelerator

Each RA4000 Controller installed in an RA4000 includes an enhanced Array Accelerator with a total of 64 MB of cache. Of that total, 16 MB is dedicated read cache that is integrated on the base controller board. The remaining 48 MB is user-configurable[5], battery-backed read/write cache located on a small, removable board that plugs into the base controller board.

For owners of the original Fibre Channel Storage System Controller with 32 MB of cache, Compaq offers a memory upgrade that expands the total memory available to 64 MB. 16 MB of dedicated read cache remains integrated on the original base controller board. The 48 MB memory upgrade is a user-configurable, battery-backed board. The default allocation of this memory cache is 50 percent read and 50 percent write. The user can configure the cache using the Array Configuration Utility.

An RA4000 Redundant Controller (64-MB cache) can be added to an existing Fibre Channel Storage System (32-MB cache). In this configuration, all write-cache is disabled and performance in certain write-intensive environments may be affected. Compaq recommends the memory upgrade kit in these types of environments.

The RA4000 Controller uses a posted write-caching scheme that allows applications to continue without waiting for write operations to complete. Without this type of caching, the controller would be forced to wait until the write data is actually written to the disk before returning completion status to the operating system.

With write-back caching, the controller can post-write data to high-speed cache memory and immediately return completion status to the operating system. The write operation is completed in microseconds rather than milliseconds. Data in the write cache is written to disk later, at an optimal time for the controller.

While data is in the write cache, it is protected against memory chip failure by Error Checking and Correcting (ECC) technology and against system power loss by integrated battery backup. The removable dynamic random access memory (DRAM) with integrated battery keeps posted-write data secure in the unlikely event that power should be lost or the base controller board should fail.

Should a system power outage occur while write data is stored in the cache, the data is protected for at least four days by power from the battery backup system.

[5] Configure cache memory using the Compaq Array Configuration Utility. Refer to “Array Configuration Utility” later in this document.

Once system power is restored, the posted-write data will automatically be written to disk. Should the base controller board fail, the small write cache board can be removed and installed on a replacement base controller board, and the posted-write data will automatically be written to disk.

The 16-MB read-ahead cache integrated on the RA4000 Controller uses an intelligent read-ahead algorithm that anticipates data needs and reduces latency. The algorithm detects sequential read activity on single or multiple I/O threads and predicts that sequential read requests will follow. The algorithm then reads data from the disk drives before the data is actually requested. When the read request occurs, the data is serviced out of the high-speed cache memory at microsecond speeds rather than from the disk drive at millisecond speeds.

When the firmware detects non-sequential read activity, the read-ahead feature is automatically disabled. This adaptive read-ahead scheme provides excellent performance for sequential small block read requests. At the same time, it avoids degradation of random read performance.

The ECC technology used on the Array Accelerator provides greater data protection than mirroring and is much more cost effective. The ECC scheme generates 16 bits of check data for every 64 bits of user data. This check data can be used to detect and correct errors. ECC can be used to detect and correct DRAM bit errors, DRAM chip failures, and memory bus errors on the Array Accelerator connector.

Compaq StorageWorks Fibre Channel Host Adapter

The Fibre Channel Host Adapter is available in either a PCI version or an EISA[6] version. The Fibre Channel Host Adapter/P is a PCI bus master device. The Fibre Channel Host Adapter/E is for use in a server equipped only with an EISA expansion bus or with a server that has a majority of EISA bus slots. It takes advantage of the EISA architecture by performing 32 bit bus master burst transfers. Both the PCI and EISA versions of the Fibre Channel Host Adapter require installation of a gigabit interface converter (GBIC) into the I/O port before the multi-mode fiber cable is connected.

In single adapter environments, the server can be connected directly to the RA4000 or multiple RA4000s using a storage hub. There are no redundant paths to ensure data availability in this configuration should a component fail.

Figure 1 through Figure 4 depict examples of some possible RA4000 configurations. For more detailed information, refer to the appropriate RA4000 manuals.

Using custom-length, 50-micron multi-mode cables, 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 single-mode cables, 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.

[6] Extended Industry Standard Architecture.

In Figure 1, the Fibre Channel Host Adapter connects to a Storage Hub 7. The Storage Hub 7 connects to the RA4000. GBICs are installed at all fiber interconnections.

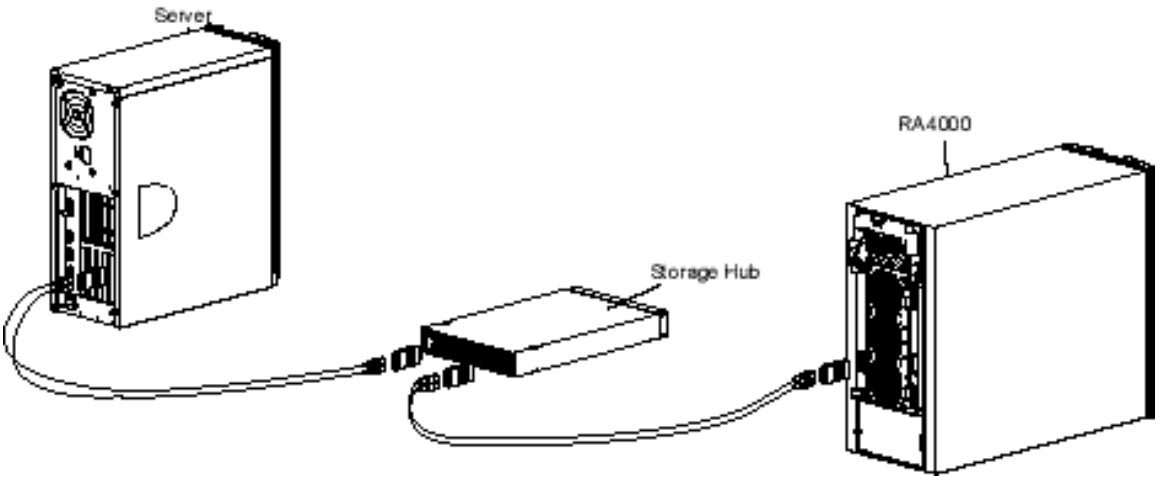

Figure 1. Single controller configuration

Additional RA4000s can be added simply by connecting them to the hub while the loop is not active. The added RA4000 can then be configured using the Array Configuration Utility[7].

Figure 2 shows that using redundant host adapters, Storage Hubs, and RA4000 Redundant Controllers, an NSPOF configuration can be deployed.

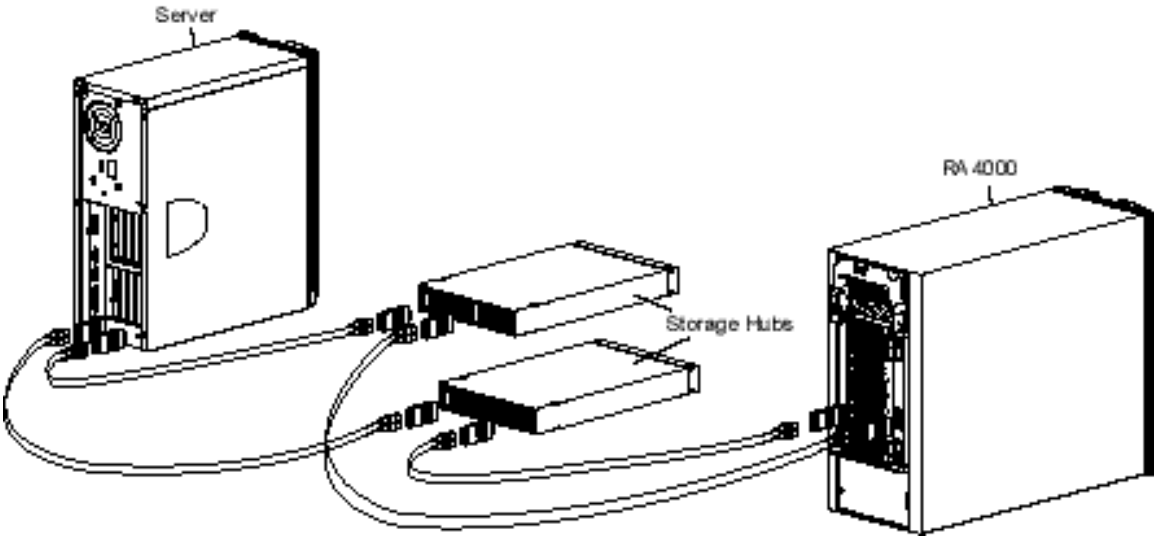

Figure 2. Redundant controllers configuration

[7] Refer to Array Configuration Utility later in this document.

Figure 3 shows that the Fibre Channel Host Adapters in an RA4000 topology can be deployed in a two-node cluster. This configuration does not provide for NSPOF.

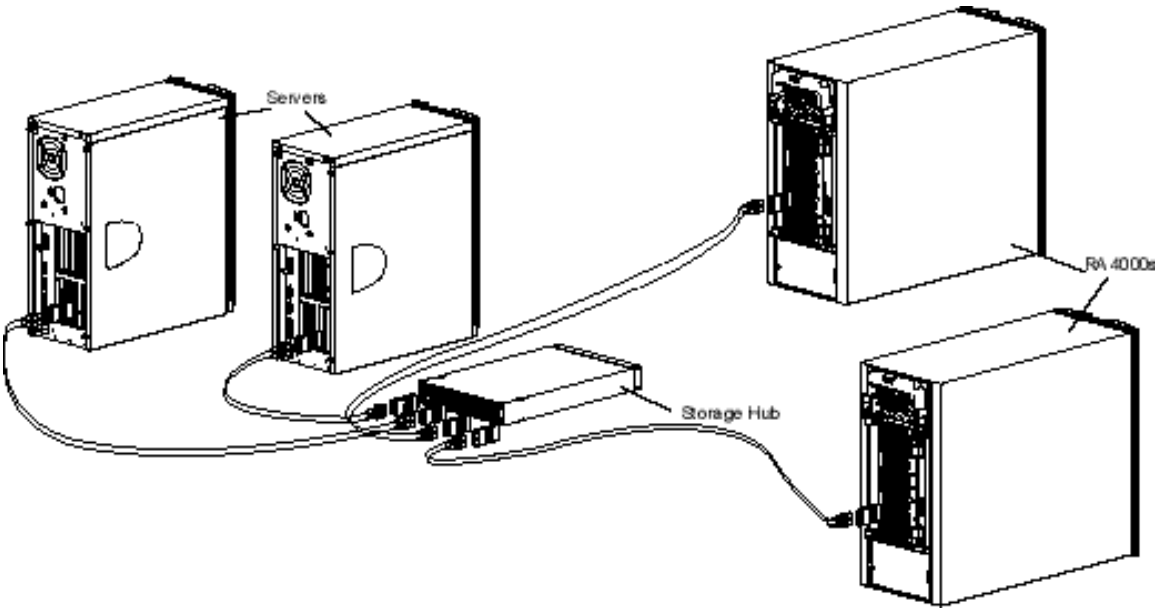

Figure 3. Single controllers in a clustered configuration

Figure 4 shows that Fibre Channel Host Adapters in a redundant topology can be deployed in a two-node cluster. This configuration provides for an NSPOF server and storage system.

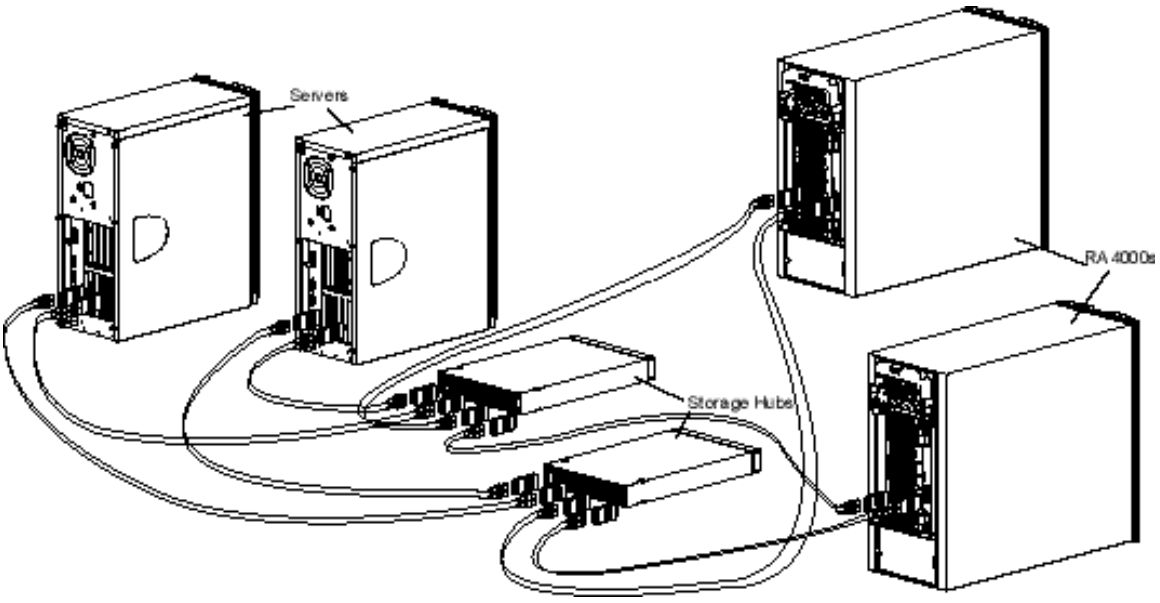

Figure 4. Redundant controllers in a clustered configuration

The Fibre Channel Host Adapter supports the Compaq ProLiant and rack-mountable ProLiant family of servers. For up-to-date information about specific server models supported, refer to the Compaq website:
www.compaq.com/products/storageworks/

StorageWorks Fibre Channel Storage Hub 7

The Storage Hub 7 is a seven-port hub that creates a 100 MB/s FC-AL through its internal wiring and logic. In a standard RA4000 configuration, it connects one Fibre Channel Host Adapter and up to six RA4000s. A 1U rack-mounting kit is available for the Storage Hub 7.

With the use of a Storage Hub 7, a Fibre Channel Host Adapter occupying a single I/O slot can support up to six RA4000s for a total storage capacity of either of the following:

- 1.75 TB using 48 x 36.4 GB, 1.6-inch drives
- 1.31 TB using 72 x 18.2 GB, 1.0-inch drives

If, for example, sufficient slots were available in a server, 8 Fibre Channel Host Adapters plugged into that server could support 48 RA4000s for a total capacity of approximately 14 TB.

RA4000s can be added to the Storage Hub 7 as requirements for storage capacity grow. When an RA4000 is added to the hub, restart all servers on the system and run the Compaq Array Configuration Utility.

StorageWorks Fibre Channel Storage Hub 12

The Storage Hub 12 is an intelligent, unmanaged, 12-port hub similar to the Storage Hub 7. Every Storage Hub 12 includes both a rack-mounting kit and rubber feet for desktop use.

With the use of a Storage Hub 12, a Fibre Channel Host Adapter occupying a single I/O slot can support up to 11 RA4000s for a total storage capacity of either of the following:

- 3.2 TB (using 88 x 36.4 GB, 1.6-inch drives)
- 2.4 TB (using 132 x 18.2 GB, 1.0-inch drives)

In a server with 8 PCI slots, Compaq Fibre Channel Storage Hub 12 allow a maximum storage capacity of more than 25.6 TB. By contrast, Compaq SMART Array Controllers can support only two ProLiant Storage Systems per I/O slot. The Storage Hub 12 is therefore the ideal solution for RA4000 configurations requiring the highest level of slot utilization and storage capacity.

Gigabit Interface Converters

GBICs are available in two varieties:

- Shortwave (GBIC-SW) for connections up to 500 meters.
- Longwave (GBIC-LW) for connections between 500 meters and 10 kilometers.

These industry-standard connection devices hot plug into the storage hubs and controllers. GBICs convert serial electrical signals into optical signals for transmission across the Fibre Channel media. GBICs also convert optical signals received from the Fibre Channel media into electrical signals.

A GBIC-SW provides:

- A transmission rate of 100 MB/s in each direction.
- A transmission distance of up to 200 meters between components using 62.5 micron, multi-mode fiber optic cable.
- A transmission distance of up to 500 meters between components using 50-micron, multi-mode fiber optic cables.

A GBIC-LW provides:

- A transmission rate of 100 MB/s in each direction.
- A transmission distance of up to 10 kilometers between components using 9-micron, single-mode fiber optic cables.

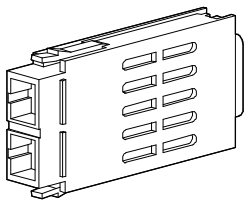

Figure 5. Gigabit interface converter

A GBIC is required for each connection in an RA4000. GBIC-SWs are provided with RA4000s and Fibre Channel Host Adapters. GBIC-LWs and single-mode fiber optic cables, as well as additional GBIC-SWs and multi-mode cables, can be purchased separately.

For trouble-free operation, keep Fibre Channel connectors and GBICs clean. To protect them from contamination, GBICs and fiber cables are shipped with dust caps installed. Remove dust caps only to make an optical connection. Reinstall the dust caps whenever the cables or GBICs are disconnected.

Compaq products ship with instructions for making clean connections. Cleaning should be performed any time that an open connection might have been exposed to dust or that there is doubt about the connector’s cleanliness. A cleaning kit is available from Compaq for this purpose.

Cables

The RA4000 uses 50-micron, multi-mode fiber optic cable, and 9-micron, single-mode fiber optic cable. The RA4000 ships with a 2-meter multi-mode cable. The Fibre Channel Host Adapter ships with a 5-meter multi-mode cable. Standard lengths for multi-mode cable option kits are 2 meter, 5 meter, 15 meter, 30 meter, and 50 meter. For installations requiring longer cable lengths, single-mode cables, or additional cables, customers may contact a Compaq reseller or special cable supplier. Refer to www.compaq.com and www.networks.digital.com/dr/opendec for more detailed information on Fibre Channel transmission, types of cable, and connection components.

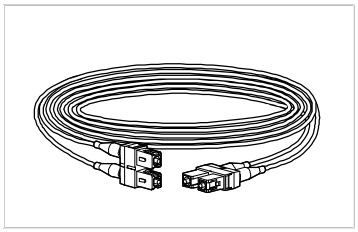

Figure 6. Fiber optic cable

Hardware Architecture

Fibre Channel is the best interconnect technology to overcome inherent I/O and physical limitations of SCSI technology and to propel future growth of enterprise storage. For its first scalable Fibre Channel storage solution for x86-based servers, Compaq selected FC-AL topology.

An FC-AL is a serial interface that creates logical point-to-point connections between ports. Because it uses the minimum number of transceivers and no centralized switching function, FC-AL provides a low-cost, yet highly flexible solution.

Each Fibre Channel node has one or more ports that enable external communication. Each port uses two fibers to communicate with its neighboring ports on the loop, one for incoming information and the other for outgoing information. All of the components that connect ports comprise the interconnect topology.

Figure 7 shows that the Storage Hub 7 contains seven serially connected ports. The Storage Hub 12, on the other hand, contains 12 serially connected ports. Internal signaling within the hubs is electrical. The internal hub connections and logic create an FC-AL. The bandwidth of the loop is shared by all ports on the loop. A single pair of ports on the loop communicates at any one time, while the other ports on the loop act as repeaters. Each port is fitted with a port bypass switch to maintain the continuity of the loop in the event a controller or device attached to that port malfunctions or is powered off. This port bypass capability improves fault tolerance.

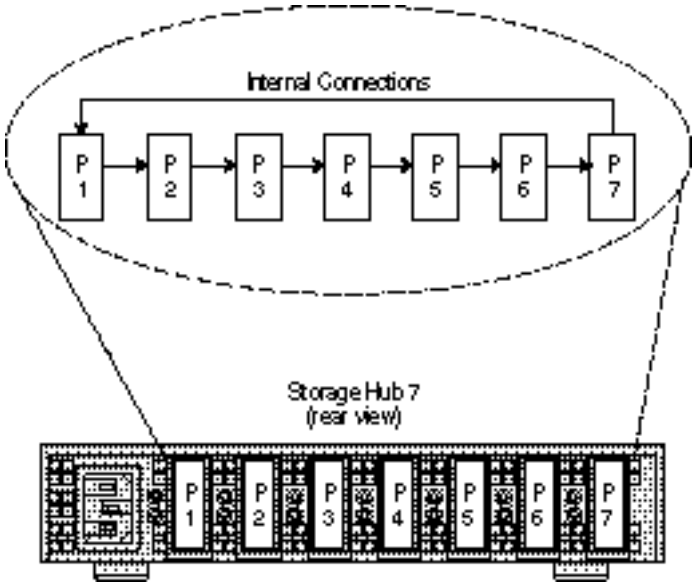

Figure 7. Compaq StorageWorks Fibre Channel Storage Hub 7

The shortwave laser technology used in the RA4000 supports transmission distances between components of up to 500 meters on 50-micron, multi-mode fiber optic cable with no electromagnetic interference. Consequently, the Fibre Channel Host Adapter can be located as much as 500 meters from the Fibre Channel Storage Hub, which in turn can be located as much as 500 meters from the RA4000s. GBIC-LW and single-mode fiber optic cables increase the point-to-point connection distance to 10 kilometers.

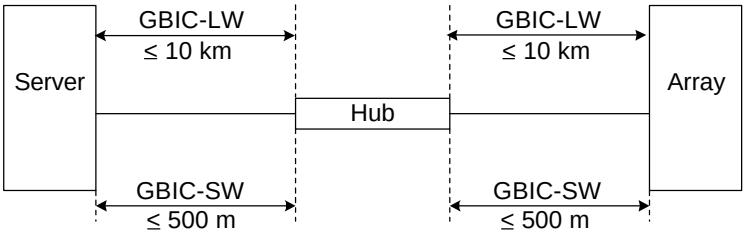

Figure 8. Possible storage configurations

Important goals in deploying the RA4000 include:

- Expanding the storage capacity accessible by a server.
- Supporting shared storage configurations.
- Enabling customers to scale storage capacity economically to meet their needs.

By moving disk array controllers outside of the server and into external drive array housings and by connecting them through a storage hub to a host-based adapter occupying a single server slot, a single server can access up to eleven RA4000s with a potential storage capacity of 3.2 TB using only one I/O slot and the Storage Hub 12.

The RA4000 supports optional online spare drives. Data availability and reliability are enhanced by RAID functionality provided in the RA4000 Controller and by the data integrity features and low error rates of Fibre Channel technology. A redundant, hot-pluggable fan assembly and an optional, redundant hot-pluggable power supply add to the subsystem availability.

The RA4000 brings NSPOF functionality to workgroup and departmental servers with optional redundant array controllers and failover software. If the active controller or other component fails or becomes inoperative in a redundant configuration, the failover software will activate the standby controller or component, notify the system administrator of the problem, and maintain operation of the storage subsystem.

This redundant technology:

- Minimizes unplanned downtime.
- Provides for enhanced scalability.
- Provides for enhanced performance[8].
- Increases availability.

Firmware

The firmware stored in read only memory (ROM) on the Fibre Channel Host Adapter and on RA4000 Controllers defines the features of the RA4000. The firmware controls RAID operation, error handling, and management information as reported to Compaq Insight Manager. The RA4000 ships with the appropriate firmware loaded. To install previously used disk drives in an RA4000, flash the disk ROM to upgrade the firmware on the used disk drives.

For easy maintenance, flash firmware upgrades for the RA4000 onto the RA4000 Controller using Compaq Options ROMPaq. It is provided on the Compaq SmartStart and Support Software CD 4.30 or later that is provided with the Fibre Channel Host Adapter. Controllers in redundant configurations must have the same firmware version (2.36 or later).

[8] For detailed informaton, refer to the RAID Array 4000 Storage System: Deployment and Configuraton White Paper.

The Compaq SmartStart and Support Software CD contains software, drivers, and utilities that automate installation of a reliable, well-integrated, and proven server configuration. This easy-to-follow program streamlines server setup, tunes the Compaq server to take full advantage of the hardware and software, and provides consistent server performance.

The RA4000 has enhanced drive array capabilities. Therefore, Compaq recommends that customers use the latest Systems ROMPaq to flash the ROM on existing servers before installing a Fibre Channel Host Adapter.

Systems ROMPaq is a special Compaq utility for updating the firmware in Compaq servers. It is also provided on the Compaq SmartStart and Support Software CD 4.30 or later.

Operating Systems Supported

Installing operating system software from the Compaq SmartStart and Support Software CD 4.30 or later ensures that required device drivers for the operating system will automatically be installed and configured.

Redundant Operating Systems Supported

RA4000 redundant configurations support the following:

- Microsoft Windows NT 4.0, Windows NT Enterprise Edition, and Microsoft Cluster Server
- NetWare 4.xx and NetWare 5.xx

Non-redundant Operating Systems Supported

The RAID Array 4000 supports the following:

- Microsoft Windows NT 4.0 and Windows NT Enterprise Edition
- NetWare 3.12, NetWare 3.20, NetWare 5.0, NetWare High Availability Server, NetWare Cluster Server, and intraNetWare
- SCO OpenServer, UnixWare 2.1, and UnixWare 7
- Banyan VINES 6.x and 7.x
- OS/2 SMP 2.11 and OS/2 Warp Server family of products
- Sun Solaris 2.5, 2.5.1, and 2.6

With the exception of the Storage Hub 12, all components of RA4000 support Microsoft Cluster Server (MSCS). After the necessary testing and integration work is complete, the Storage Hub 12 will also support Microsoft Cluster Server. For the most up-to-date information about software support, refer to the Compaq website:
www.compaq.com

Compaq Utilities

Compaq has developed the following utilities to simplify configuration and maintenance of the RA4000:

- Array Configuration Utility
- Fibre Fault Isolation Utility
- User Diagnostics Utility
- Array Diagnostics Utility
- Compaq Insight Manager
- Compaq Redundancy Manager

Array Configuration Utility

The Compaq Array Configuration Utility (ACU) uses a graphical interface to streamline configuration of RA4000s. It contains intuitive, online configuration wizards that provide guided paths for complete array configuration. It also contains customized paths for administrators needing complete control over configuration options. ACU 1.20 and later provides an interface to intelligent features of the RA4000 Controller that make it easy for administrators to configure, modify, expand, manage, and monitor their storage.

The ACU is provided on the Compaq SmartStart and Support Software CD 4.30 or later. It can be used to:

- Perform initial configuration of the RA4000 Controller.
- Add disk drives to an existing configuration.
- Reconfigure the controller.

The Array Configuration Utility:

- Illustrates the controller configuration in an easy-to-understand graphical format.
- Contains configuration wizards that walk the administrator through the configuration process.
- Suggests optimal configuration and fault tolerance for unconfigured controllers.
- Identifies various configuration errors.
- Indicates the physical location of drives being configured.

Using the Compaq ACU, an administrator can quickly assign physical drives to an array. Up to 4 drives can be assigned as online spares, and from 1 to 32 logical drives can be created per controller. The ACU steps through each logical drive configuration until all space is allocated. Fault tolerance levels can be selected on a logical drive basis.

Custom configuration paths allow the administrator to examine the details of both logical and physical views and make specific configuration changes if necessary. Graphical views of the array and the logical drives make it easy to visualize how the storage is configured.

Capacity expansion is done at the array level, not at the logical drive level. In most cases, all disk drives attached to a controller should be grouped together into a single array. This provides the most efficient use of RAID redundancy.

In designing the ACU for the RA4000, Compaq added some new features to assist administrators. For example, to help an administrator remember the physical location of the drive being configured, all three light-emitting diodes (LED) on the physical drive tray for that controller will flash.

The new user interface in this ACU displays more information such as the ID assigned to each RA4000 on the FC-AL. The administrator can change these ID assignments in the Controller Settings window.

The Compaq ACU originally was designed to configure a maximum of eight controllers. Currently, Windows NT supports a maximum of eight logical drives in an RA4000. In maximum configuration environments, the ACU may operate a bit slower than expected. The ACU displays an hourglass cursor to indicate that it is processing.

Fibre Fault Isolation Utility

Since the RA4000 is the first Compaq product to use a FC-AL topology and the loop includes many components, Compaq developed two new support tools found on the SmartStart and Software Support CD:

- Fibre Channel Troubleshooting Guide
- Fibre Fault Isolation Utility

The troubleshooting guide describes components of the RA4000 and discusses the Fibre Fault Isolation Utility. The troubleshooting guide contains flowcharts and other information for troubleshooting.

The Fibre Fault Isolation Utility verifies the installation and operation of a new or existing RA4000. When used with the troubleshooting flow charts, this utility provides fault detection and helps to isolate problems on the FC-AL.

Before configuring the system, run the Fibre Fault Isolation Utility as soon as all hardware components of the RA4000 have been connected. This utility runs offline[9] on the server. It shows each Fibre Channel Host Adapter and each RA4000 that is properly connected on the loop. If one of these components is not displayed on the screen, the *StorageWorks Fibre Channel Troubleshooting Guide* should be consulted to determine why.

The Fibre Fault Isolation Utility displays all devices that are properly logged on to the FC-AL and tests for link errors within the loop. A link is that portion of the loop between the Fibre Channel Host Adapter and a storage hub or between a storage hub and the RA4000.

[9] In this case, offline means equipment that is turned off, not operating, or is not physically connected to the system.

User Diagnostics Utility

If the Fibre Fault Isolation Utility indicates that a fault exists, run the User Diagnostics Utility that Compaq developed for enterprise systems. The User Diagnostics Utility is a group of hardware diagnostic tests designed to test the RA4000 and attached SCSI drives. This utility can isolate a fault to a specific drive within an RA4000 or to a specific component in the loop. The StorageWorks Fibre Channel Troubleshooting Guide and the User Diagnostics Utility can find the cause of potential faults in an RA4000 system and Fibre Channel connections.

The hardware diagnostic tests within the User Diagnostics Utility are grouped into two test modes.

The first test mode, which runs on a notebook computer or a handheld PC, takes advantage of the built-in self-test on the RA4000 Controller to determine which subsystem is failing. Tested components include cache, RAM, PCI bus, SCSI bus, LEDs, RA4000 Controller, power supply, system fans, GBICs, and fiber cable. This first test mode also displays information about the RA4000 Controller, such as firmware revision, worldwide name, and board serial number.

The second test mode, which runs on a server through the Fiber Channel interconnect, displays the array controllers and logical volumes found, configuration revisions, and firmware revisions. These tests simultaneously exercise multiple logical volumes and trap any error conditions.

The User Diagnostics Utility is available on the Compaq SmartStart and Support Software CD 4.30 or later that is provided with Compaq servers and that ships with the Fibre Channel Host Adapter kit. There are two versions of User Diagnostics on the CD:

- Windows 95 (to run on a server or notebook computer)
- Windows CE (to run on a handheld PC)

The two versions are separate executables. Both versions perform the first test mode. Only the Windows 95 version performs the second test mode.

Note: With Compaq SmartStart and Support Software CD 4.30, the first test mode of the User Diagnostics Utility operates only when the utility is run on a notebook computer or a handheld PC.

Running the User Diagnostics Utility is simple, but it requires slightly different steps, depending on whether the administrator runs the utility on a server, notebook, or handheld PC. Table 3 in the appendix summarizes how to access and run the User Diagnostics Utility from the three types of machines.

Array Diagnostics Utility

Because array controllers are complex devices, Compaq provides an Array Diagnostics Utility (ADU) to help administrators quickly identify problems. The ADU identifies such problems as:

- An incorrect version of firmware.
- Drives that are installed in the wrong order.
- Inappropriate error rates.
- A failed battery on the Array Accelerator board.

The ADU displays a more detailed analysis of the system configuration than the ACU does. If the cause of a problem is still not apparent, the ADU can generate a full report that administrators can fax or email to Compaq customer service for telephone support.

An offline version of the ADU is provided on the Compaq Support Software CD 4.30 or later. The ADU is designed for use not only with RA4000 Controllers, and with Compaq SMART-2 and SMART Array Controllers.

Compaq Insight Manager

Compaq Insight Manager is a client-server SNMP[10]-based tool for integrated management of the server environment. It monitors performance and other operating characteristics of SMART-2 or RA4000 Controller-based storage. It displays configuration information, operating system device driver version numbers, controller firmware version numbers, Pre-failure Warranty information, and operating statistics. The RA4000 is supported by Compaq Insight Manager 3.60 and later.

Insight Manager warns administrators of potential drive problems before they occur. A background task monitors several essential drive parameters and notifies Insight Manager if a drive fails to meet certain preset criteria. Insight Manager, then alerts the administrator to the potential problem.

Compaq Redundancy Manager for Microsoft Windows NT

The Compaq Redundancy Manager software is a redundancy management utility for servers using the RA4000 in configurations with NSPOF. The Redundancy Manager configures the environment with using redundant Fibre Channel Host Adapters.

The Redundancy Manager automatically configures multiple paths with the first available path being set as Active and the next path as Standby. It can be manually configured to have Active/Active paths to allow load balancing of the system and to have multiple paths active at once.

The Redundancy Manager operates on Compaq ProLiant servers and supports the following operating systems:

- Microsoft Windows NT Server
- Microsoft Windows NT Server Enterprise Edition

[10] Simple network management protocol

Performance

The RA4000 scales capacity and performance simultaneously. Each RA4000 adds processing power and cache to the overall system. The more hard drives an RA4000 contains, the higher the I/O performance scales. This fact is best illustrated by comparing the maximum number of I/O transactions per second per PCI server slot provided by an RA4000 to the maximum number provided by a ProLiant Storage System controlled by a Smart Array 3200 (SA3200) Controller[11] (see Figure 9 and Table 2).

In comparative tests performed in Compaq laboratories, test engineers used 2 KB random accesses to simulate an online transaction processing (OLTP) application. The accesses were 67 percent reads and 33 percent writes. The test results shown in Figure 9 indicate that a Compaq SA3200 Controller occupying a single PCI server slot can support approximately 939 simulated OLTP I/O per second. The RA4000, on the other hand, can support approximately 928 OLTP I/O per second using a single PCI server slot.

Figure 9 shows that the SA3200 Controller gives better performance than the RA4000 up to a point. The RA4000 scales linearly far beyond the capabilities of SCSI technology. The high capacity and performance scalability make the RA4000 an ideal storage solution for large, power-hungry databases.

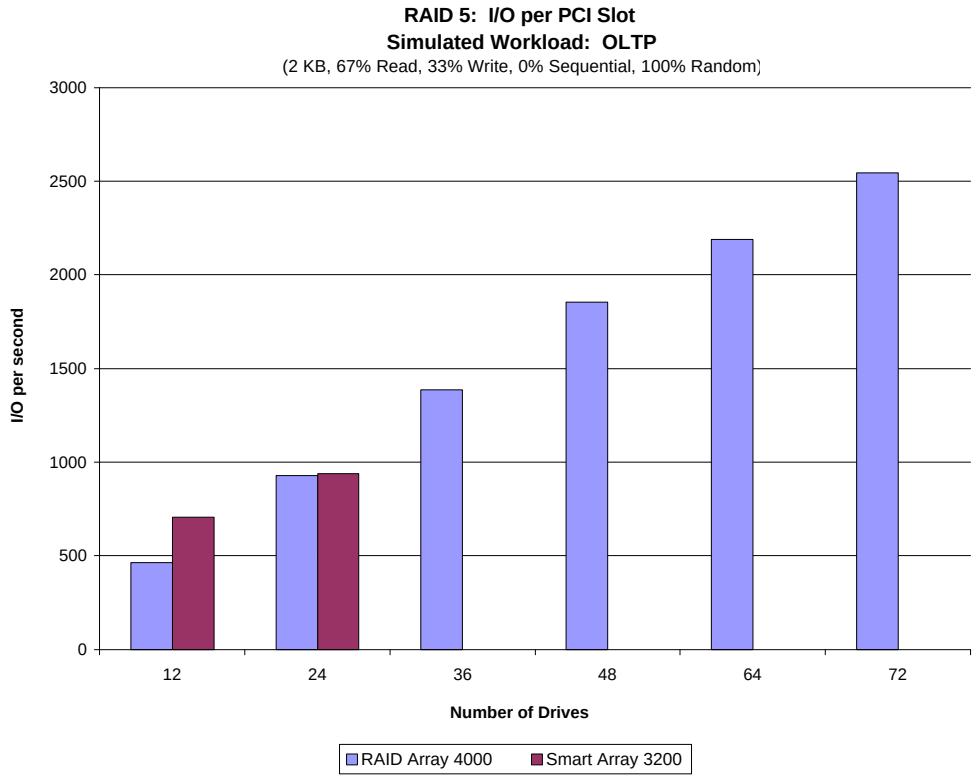

Figure 9. Performance scalability of a Fibre Channel system with a simulated workload

[11] The SA3200 Controller is a SCSI device.

Table 2. Comparison of three Compaq storage systems

	Smart Array 3200 Controller and ProLiant Storage System/UE		RAID Array 4000	
Type of Drives	1 inch, 18.2 GB	1.6 inch, 36.4 GB	1 inch, 18.2 GB	1.6-inch, 36.4 GB
Maximum Drives per Server Slot	12	8	132	88
Capacity/Slot				
TOTAL	218.4 GB	291.2 GB	2.4 TB	3.2 TB
RAID 5	200.2 GB	259.8 GB	2.2 TB	2.8 TB
RAID 1	109.2 GB	145.6 GB	1.2 TB	1.6 TB
RAID 5 + Spare	182.0 GB	218.4 GB	2.0 TB	2.4 TB
Transfer Distance	12.0 m (39.4 ft)	12.0 m (39.4 ft)	GBIC-SW: 500 m (1,640 ft) GBIC-LW: 10 km (32,808 ft)	GBIC-SW: 500 m (1,640 ft) GBIC-LW: 10 km (32,808 ft)
Capacity Growth Rate	Moderate	Moderate	Fast	Fast
Fault Tolerance	Hard Drive	Hard Drive Write cache backup	Hard Drive Write cache backup	Hard Drive Write cache backup
Applications	Branch office and departmental file and print Groupware Communications	Departmental and centralized file and print Groupware/web Centralized communications database	Centralized, high-capacity file and print Groupware/web High-capacity and high-performance database Data marts	Centralized, high-capacity file and print Groupware/web High-capacity and high-performance database Data marts

Migration to RA4000 from SCSI Technology

Incompatibilities in bus and drive mapping exist between Compaq ProLiant Storage Systems and the RA4000. For this reason, data stored on hard drives in a ProLiant Storage System connected to a Smart Array Controller cannot be migrated directly to an RA4000. Instead, migrating stored data from an existing storage system to an RA4000 requires a full backup and restore operation. Refer to www.compaq.com for details about migrating to an RA4000 from a Compaq ProLiant Storage system using the Compaq SMART Array controllers.

Clustering with RA4000

A cluster is a loosely coupled collection of servers and storage devices that are managed by cluster management software. Clustering provides high availability of applications and data and performance scalability.

Clustering with RA4000 systems benefits business-critical application because RA4000 technology ensures that applications stay up and running through:

- Redundant components in storage.
- Hot-plug and redundancy in servers.
- Software that provides failover of hardware.

Clustered RA4000s provide investment protection and flexibility in certain configurations. Hardware can be in matched- or mix-pair configurations tailored to meet the needs of the computing environment.

Compaq software enables rapid installation, configuration monitoring and management, and deployment of clustered environments throughout the enterprise. Compaq SmartStart and Compaq Insight Manager are now cluster enabled, allowing easy installation and sophisticated management, either locally or from remote locations.

Compaq installation and systems management software, along with MSCS software, brings easy, efficient cluster administration for MSCS clusters. NetWare High Availability Cluster is also supported while NetWare Cluster Services will be supported after the product initially ships.

Compaq servers, RA4000 storage, server-to-server interconnect options, system software, and implementation documentation have all been thoroughly tested in a variety of cluster configurations and with many standard applications. These tests have resulted in Compaq solutions that have the means to deliver higher levels of application availability at much lower costs than traditional, proprietary cluster solutions.

For More Information

For additional information about Fibre Channel technology and the Compaq StorageWorks RAID Array 4000, refer to:
www.compaq.com

APPENDIX A: User Diagnostics Utility

Table 3 summarizes the steps required to run the Compaq User Diagnostics Utility on a Compaq server, notebook computer, or handheld PC.

Table 3. Compaq User Diagnostics Utility for server, notebook computer, or handheld PC

Step	Server	Notebook	Handheld PC
1.	Take the server offline.	Use the Diskette Builder on the Compaq SmartStart Support Software CD 4.30 or later containing the Windows 95 version of the User Diagnostics Utility.	Use the Diskette Builder on the Compaq SmartStart and Support Software CD 4.30 or later containing the Windows CE version of the User Diagnostics Utility.
2.	Boot the server from the Compaq SmartStart and Support Software CD 4.30 or later.	Use the diskette to install the User Diagnostics Utility on the notebook computer.	Use the diskette to install the User Diagnostics Utility on a desktop computer.
3.	Run the Windows 95 version of the User Diagnostics Utility.	Using a serial cable, connect the notebook computer to the serial port on the RA4000.	Using a serial cable, connect the handheld PC to the desktop computer.
4.		Run User Diagnostics on the notebook computer.	Download User Diagnostics from the desktop computer to the handheld PC.
5.			Disconnect the handheld PC from the desktop computer.
6.			Using a serial cable, connect the handheld PC to the serial port on the RA4000.
7.			Run User Diagnostics on the handheld PC.