TECHNOLOGY BRIEF

June 1998

Compaq Computer Corporation

ECG Technology Communications

CONTENTS

PCI Hot Plug Technology with Novell® Architecture

As an increasing number of companies migrate their business-critical applications to industry-standard servers, the need for high-availability solutions to minimize system downtime is increasing. Compaq, the world's leading server provider, has historically taken a leadership role in developing industry-standard technologies. With the development of PCI Hot Plug technology, Compaq strengthens its role in providing high-availability solutions for the enterprise.

Novell Inc. is a leader in the development of network operating systems. NetWare™, developed by Novell, is the most widely used network operating system in the world. Because of Novell's expertise in this area, NetWare is perfectly suited for integration of PCI Hot Plug capabilities, especially Compaq's leading implementation. Compaq and Novell have worked together to develop the software needed to give administrators full hot-plug capability. This technology brief provides information on the joint effort between Compaq and Novell to implement PCI Hot Plug technology.

Please direct comments regarding this communication to the ECG Technology Communications Group at this Internet address: TechCom@compaq.com

NOTICE

The information in this publication is subject to change without notice and is provided "AS IS" WITHOUT WARRANTY OF ANY KIND. THE ENTIRE RISK ARISING OUT OF THE USE OF THIS INFORMATION REMAINS WITH RECIPIENT. IN NO EVENT SHALL COMPAQ BE LIABLE FOR ANY DIRECT, CONSEQUENTIAL, INCIDENTAL, SPECIAL, PUNITIVE OR OTHER DAMAGES WHATSOEVER (INCLUDING WITHOUT LIMITATION, DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION OR LOSS OF BUSINESS INFORMATION), EVEN IF COMPAQ HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

The limited warranties for Compaq products are exclusively set forth in the documentation accompanying such products. Nothing herein should be construed as constituting a further or additional warranty.

This publication does not constitute an endorsement of the product or products that were tested. The configuration or configurations tested or described may or may not be the only available solution. This test is not a determination of product quality or correctness, nor does it ensure compliance with any federal state or local requirements.

PCI Hot Plug Technology with Novell® Architecture

Second Edition (June 1998)
ECG081/0698

INTRODUCTION

Customers today need high-availability solutions that minimize or eliminate downtime. PCI Hot Plug technology allows a PCI adapter to be added, upgraded, or replaced while the host system is running and while other adapters in the system provide uninterrupted service. PCI Hot Plug technology adds to other high-availability solutions presently available from Compaq such as Recovery Server Options, Redundant Netelligent Network Interface Controllers (NICs), hot-pluggable power supplies, hot-pluggable fans, and hot-pluggable SCSI drives.

Three PCI Hot Plug Capabilities

PCI Hot Plug technology provides for three major capabilities: hot replacement, hot upgrade, and hot expansion.

Hot replacement is the process of removing a failed or failing PCI adapter and inserting an *identical* adapter into the same slot while the server is operating.

Hot upgrade is the process of replacing an existing adapter with an *upgraded* adapter or replacing the adapter's device driver with an upgraded device driver while the server is operating.

Hot expansion is the process of installing an *additional* adapter into a previously empty slot while the server is operating.

Synergistic High-Availability Techniques

PCI Hot Plug technology represents a significant advance in fault-tolerant systems. To provide even greater benefit, PCI Hot Plug technology can be combined with redundant controller configurations, such as Compaq Redundant Netelligent NIC technology.

Compaq Redundant Netelligent NIC technology allows two similar NICs to share a single instance of device driver code. One NIC becomes the active network controller, and the other NIC acts as a standby controller. If the active NIC fails, the network traffic can be switched automatically to the standby NIC. With PCI Hot Plug, the failed NIC can be replaced without shutting down the system. Thus, the end user can have continuous service and the administrator can eliminate both planned and unplanned downtime.

Progress Toward an Industry Standard

Since Compaq's June 1996 announcement to deliver PCI Hot Plug technology as an open, industry standard, Compaq has worked with key hardware and software partners and the industry-wide PCI standards committee. This effort allows customers to move forward in implementing this technology with greater flexibility. Compaq has taken several steps to ensure broad industry acceptance of the technology, including:

- Standardized PCI Hot Plug technology by initiating and chairing the PCI Special Interest Group (SIG) Hot Plug Workgroup. The workgroup included other industry leaders such as Adaptec, Inc.; Cirrus Logic, Inc.; Digital Equipment Corporation; Hewlett-Packard Company; IBM Corporation; Intel; Microsoft; Novell; Pro-Log Corporation; The Santa Cruz Operation, Inc. (SCO); and Texas Instruments Incorporated. Efforts of the workgroup allowed a quick release of the PCI Hot Plug Specification—only 14 months from the group's charter. For more information on the PCI Hot Plug Specification, visit the PCI SIG website at http://www.pcisig.com.

- Partnered with operating system (OS) developers to ensure incorporation of the PCI Hot Plug standard in product releases. Compaq has taken a proactive role in ensuring broad OS support for hot-plug capabilities. Actions to date range from the development of cross-company design teams to the delivery of PCI Hot Plug platforms for testing OSs. Currently, Microsoft, Novell, and SCO support PCI Hot Plug.
- Worked with leading adapter vendors such as 3Com Corporation; Adaptec; Dialogic Corporation; Digi International; Mylex Corporation; QLogic Corporation; American Megatrends, Inc.; Madge Networks; SMC Networks Inc.; and SysKonnect to ensure broad acceptance and rapid implementation of the standard.
- Licensed PCI Hot Plug technology to be available in Intel architecture-based server platforms. Intel will incorporate Compaq's implementation of PCI Hot Plug, including the hot-plug controller and related system technologies, in future products.
- Developed hot-plug aware drivers for Compaq NetFlex controllers, Netelligent controllers, Smart array controllers, and Fast-Wide SCSI-2 controllers.
- Developed the Compaq ProLiant 6500 and ProLiant 7000, announced in August 1997, as the first available server platforms conforming to the PCI Hot Plug Specification and added next-generation PCI Hot Plug features to Pentium II Xeon Models of the ProLiant 7000 announced in June 1998.

Compaq is in a unique position to lead this standardization effort. Not only is Compaq a pioneer in the development of systems hardware, but Compaq also has extensive experience in systems configuration software and device driver development. Because of its unique position, Compaq has been able to gather the support of major software developers and independent hardware vendors (IHVs) to deliver PCI Hot Plug technology as an open, industry standard.

The Compaq technology brief *PCI Hot Plug Technology*, document number ECG080/0698, outlines additional details of Compaq's overall strategy regarding this technology.

Compaq and Novell Team Up

Novell is an expert in the development of network OSs and standardized driver architectures. Compaq has expertise in the development of systems hardware, systems configuration software, device drivers, and the design of high-availability solutions. In December 1995, engineers from Novell and Compaq formed a team to design a standard software architecture to provide PCI Hot Plug support for Novell's NetWare operating system.

Through the unique capabilities, benchmarking, and team efforts of Compaq and Novell, the business community can reap great benefit from the quality products produced by this effort.

SYSTEM OVERVIEW

PCI Hot Plug functionality requires both hardware and software components. A fully capable hot-plug system includes the hot-plug system hardware, a hot-plug aware OS and user interface (as provided by the Novell NetWare architecture), hot-plug system drivers, and hot-plug capable device drivers.

Most industry-standard PCI adapters can be used in Compaq's hot-plug environment without modification; however, their device drivers require new features to use hot-plug capabilities. A PCI adapter can be installed without using its hot-plug functionality until all the previously mentioned components are in place. PCI Hot Plug technology is backward compatible and can be incrementally incorporated by customers as they add or replace servers or components. This allows a mixture of existing components and new hot-plug technology to be used at the same

time. It also protects the substantial investment customers have made in network hardware and allows them to gradually move toward improved system availability in a cost-effective manner.

System Hardware

It is important to note that while the PCI Hot Plug Specification identifies the technical requirements of a hot-plug capable system, it does not specify the implementation of this technology. In the specific implementation that Compaq developed, the PCI Hot Plug hardware isolates a single PCI slot from all other devices on the PCI bus. Compaq's PCI Hot Plug system hardware performs two main functions:

- Powers down a single adapter slot, allowing insertion and removal of adapters
- Protects the system and other adapters from the electrical effects of hot-plug operations

Hot-Plug Controller and Slot-Specific Power Control

The hot-plug electronics designed by Compaq consist of two separate elements: the hot-plug controller and the slot-specific power control. Compaq designed its hot-plug controller to manage the following components:

PCI Bus. The controller communicates with isolation devices on the PCI bus to electrically isolate a single PCI slot from the rest of the system. Slot isolation permits insertion or removal of an adapter without interruption to the server or other active adapters.

Power. The controller receives a command from the OS to power up or power down a single PCI slot. To perform this function, the controller uses the slot-specific power control. The slot-specific power-control electronics allow the proper power sequencing on the PCI bus and guarantee safe control of the power to the individual PCI adapters.

Slot LED Indicators. The hot-plug controller also governs the slot LEDs. In Compaq's implementation of hot-plug hardware, each slot has a green and an amber LED to indicate slot status. The green LED indicates power to the slot and flashes while performing a power state change; the amber LED indicates that the slot requires attention.

PCI Hot Plug Button. This feature is available only on Compaq's latest PCI Hot Plug servers. The button is pressed to signal the software to initiate a power state change. While the button is more convenient, the same functionality is provided through the software interface. Each slot has its own button to indicate which slot is to be addressed by the supporting software.

System Chassis Design

In addition to the electrical components, the overall system design (system chassis and other hardware) has been adapted for safety and ease of adapter installation and removal. Chassis design changes include: quick-release latches on the adapter slots to allow fast and easy removal and insertion of adapters; wider slot spacing and flexible slot separators to allow users to remove and insert adapters without electrically contacting (shorting) other components; and a top access shield that allows users access to adapters yet prevents access to other internal components. These design changes meet or exceed all regulatory safety standards.

Novell NetWare System Architecture

The PCI Hot Plug architecture leverages the inherent modularity of NetWare to minimize the changes required for third-party adapter software. The system relies on a central component, the Novell Event Bus, which facilitates communications between the different software modules. Figure 1 illustrates the key components of the NetWare PCI Hot Plug architecture.

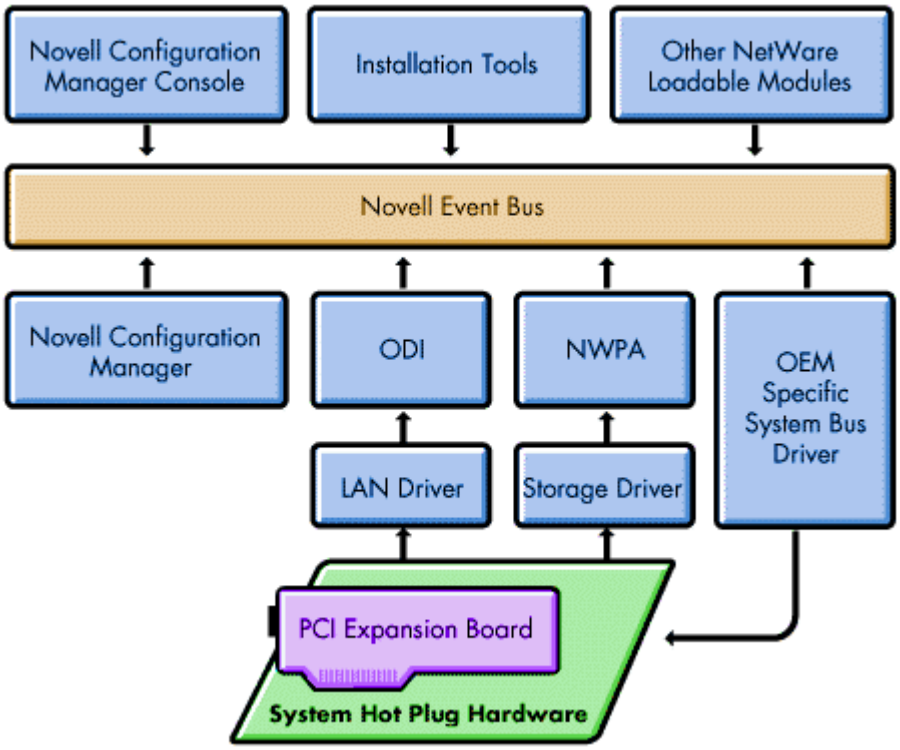

Figure 1: Novell NetWare Hot Plug Architecture

Novell Event Bus

The most important component of the PCI Hot Plug software architecture is the Novell Event Bus. This software bus facilitates communication between the administrator, the software modules, management agents, and device drivers, providing the foundation for the software architecture. The Event Bus was first implemented as a Network Loadable Module (NLM), allowing implementation of PCI Hot Plug on existing versions of NetWare. NetWare 5.0 integrated the Event Bus into the OS kernel.

Novell Configuration Manager

For PCI Hot Plug servers, the Novell Configuration Manager manages the hot-plug system and ensures proper system behavior. Its primary function is to sequence hot-plug operations to ensure stability of the system. To achieve this function, the Configuration Manager properly shuts down the adapter's device driver before removing power from the slot. Another main role of the Configuration Manager is to map hardware resources to device driver software. Future releases of NetWare will have an enhanced Configuration Manager to encompass other technologies in addition to PCI Hot Plug.

Novell Configuration Manager Console

The Novell Configuration Manager Console is necessary to perform hot-plug functions in NetWare systems. This NLM provides the interface for controlling all hot-plug operations. In addition, it displays slot configuration details, including adapter driver information and status.

The Configuration Manager Console consists of two screens: the Main Menu and Slot Detail Information. The Main Menu displays a list of all PCI slots in the system. For each slot, the Main Menu displays the following information, as shown in Figure 2:

- Slot number
- Slot hot-plug status
- Product name or description of the adapter
- Status of the slot and adapter

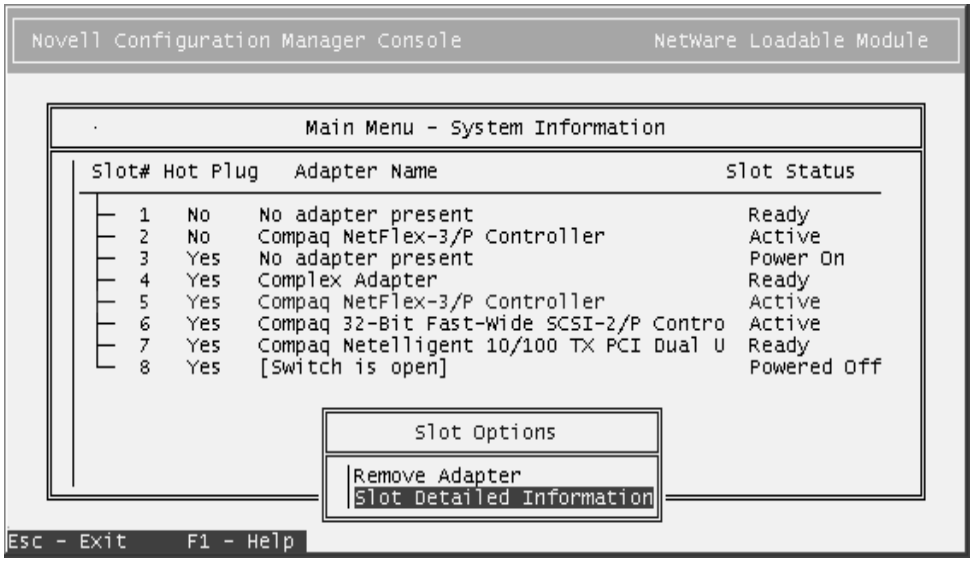

Figure 2: Configuration Manager Console Main Menu Screen

Pressing **ENTER** on a selected slot of the Main Menu will either produce a menu of slot options (Remove, Replace, or Slot Detail Information) or take the user directly to the Slot Detail screen. On-line, context-sensitive help is available to guide the user through PCI Hot Plug actions.

The Slot Detail screen (Figure 3) displays information about a specific slot and the adapter in that slot. This information includes the following:

- Slot number
- Adapter name or description
- Bus number and type associated with that slot
- Slot and adapter hot-plug status
- Device and driver information associated with the adapter

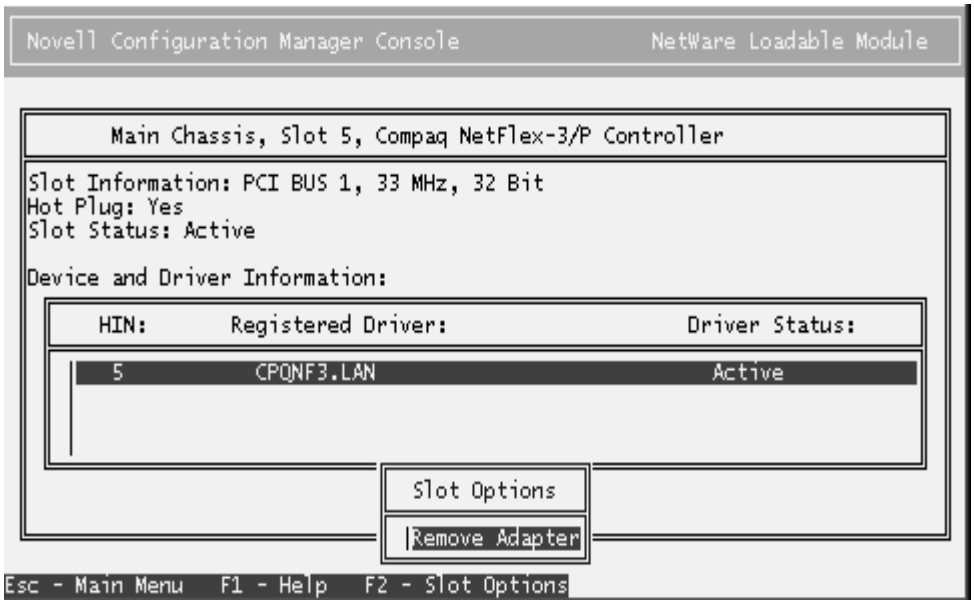

Figure 3: Configuration Manager Console Slot Detail Screen

Pressing **F2** activates the Slot Options menu, which allows the administrator to perform actions such as removing, replacing, or adding an adapter in that particular slot.

Installation Tools

NetWare provides **INSTALL.NLM**, which allows users to locate the required device drivers and properly configure adapters. When adapters have been added to the system, **INSTALL.NLM** automatically determines the need and searches for the appropriate additional device drivers.

Hot-Plug System and Device Drivers

OEM Specific System Bus Driver

Compaq, as well as other original equipment manufacturers (OEMs), provides a system bus driver specific to their PCI Hot Plug hardware implementation. The NetWare architecture allows multiple system bus driver modules to exist simultaneously.

The system bus driver abstracts the OEM's platform-specific implementation of PCI Hot Plug. This driver controls the system hardware necessary to perform hot-plug functions and is responsible for the following:

- Enabling or removing power from a hot-plug slot upon request
- Configuring hardware and assigning resources like memory, input/output ports, and interrupts of PCI adapters in hot-plug slots

The Compaq System Configuration Utility provides a Hot Plug Reservation Table that, when enabled, works with the system bus driver to enable the addition of new PCI devices without the need to reconfigure existing devices. When the table is disabled, PCI Hot Plug expansion is not possible, but adapters can still be removed or replaced.

Device Drivers

The minimal support required for hot-plug functionality is the ability to shut down a single instance of the device driver. When removing an adapter from the system, notification and shut down of the associated device driver must take place through the Novell Configuration Manager Console or through the PCI Hot Plug Button before removal of slot power. This prevents software errors.

ODI – The Open Data-Link Interface (ODI) for networking support specifies the driver architecture for network devices. Modified slightly, the ODI specification encompasses PCI Hot Plug technology. Because of the inherent modularity of NetWare, the changes required to third-party adapter device drivers are minimal.

The ODI architecture standardizes the support for network PCI Hot Plug drivers by providing a translation layer between the specific device drivers and NetWare. This translation layer, called ODINEB, abstracts the ODI device drivers (hardware specific modules) from the PCI Hot Plug system. Device drivers compliant with the modified ODI specification will be PCI Hot Plug compatible and will continue to work in non-hot-plug environments.

To obtain PCI Hot Plug functionality, local area network drivers should be compliant with the ODI 3.31 specification.

NWPA – The NetWare Peripheral Architecture (NWPA) specifies the driver architecture for storage devices. The NWPA specification, modified slightly, encompasses PCI Hot Plug technology. Because of the inherent modularity of NetWare, the changes required in third-party device drivers are minimal.

NWPA standardizes the support for storage PCI Hot Plug drivers by providing a translation layer between the specific storage device drivers and NetWare. Device drivers compliant with the modified NWPA specification are PCI Hot Plug compatible and will continue to work in non-hot-plug environments.

Drivers written to the DDFS specification, NWPA's predecessor, do not support hot-plug technology. Therefore, storage drivers must be converted to NWPA to obtain hot-plug functionality.

Other Adapters – To enable other types of device drivers to support the PCI Hot Plug feature set, the Novell NetWare system architecture allows for NLMs to interact directly with the Event Bus. By sending and receiving PCI Hot Plug events, an NLM can perform all functions necessary for PCI Hot Plug.

HARDWARE AND SOFTWARE CONTROL

In a typical scenario in which the administrator adds an adapter to an empty slot, the following steps occur while the system is running:

1. The administrator prepares the slot for installation of the adapter by opening the appropriate slot release lever and removing the expansion slot cover.
2. The administrator installs the adapter into the appropriate expansion slot.
3. The administrator closes the slot release lever.
4. The administrator uses the Novell Configuration Manager Console or the PCI Hot Plug Button to notify NetWare that power can be applied to the slot. The green LED will flash while NetWare is performing the power state change.
5. The Novell Configuration Manager will turn on power to the slot and use **INSTALL.NLM** to automatically locate and load the appropriate device driver.

CONCLUSION

With the introduction of PCI Hot Plug technology, Compaq once again set the standard in high-availability and fault-tolerant solutions for the enterprise. PCI Hot Plug offers unprecedented server availability by allowing users to replace, upgrade, and add PCI adapters to the PCI local bus without powering down the server. With the release of the ProLiant 6500 and ProLiant 7000, Compaq made the chassis and electronics design changes required for safe and efficient removal and insertion of PCI adapters without powering down the server. Next-generation PCI Hot Plug features are included in Compaq's newest enterprise server, the Pentium II Xeon Model of the ProLiant 7000, released in June 1998.

Novell is a leading OS developer whose NetWare technology is perfectly suited for integration of PCI Hot Plug capabilities. Compaq has worked closely with Novell to develop hot-plug capabilities for NetWare.

PCI Hot Plug technology brings significant advances to the other high-availability solutions Compaq currently offers. By bringing this technology to the market as an open, industry standard, Compaq continues to strengthen its position as a leader in enterprise computing.