COMPAQ
Integration Note

Contents

PCI Bus Numbering in a Microsoft Windows NT Environment

Abstract: Computing environments change rapidly to support business requirements. Typical network PCI-based servers contain a large number of expansion slots on multiple buses to allow for system growth. This means that multiple network and disk controllers of the same type may be installed in one server, with the intent that each installed controller supports a separate unique function. This can make it difficult to understand the physical and logical implications of PCI bus numbering.

This document provides information to help systems engineering professionals understand how Microsoft Windows NT handles PCI bus numbering when controllers are physically added, moved, or removed from a server configuration. This document also includes ideas and suggestions that can help systems professionals avoid network downtime due to configuration changes.

IMPORTANT: During the development of Microsoft Windows 2000, Compaq and Microsoft worked closely together effectively implementing Windows 2000 on Compaq hardware. Through this partnership, device detection improved, eliminating PCI bus numbering issues in the Windows 2000 environment. Windows 2000 checks and resets registry settings automatically, unlike its predecessor that does not reset the registry settings after discovering unbound devices.

The following documents were either used as references to produce this white paper or are mentioned as recommended related reading material:
- *PCI System Architecture, Third Edition, MindShare, Inc. Tom Shanley and Don Anderson, November, 1995.*
- *PCI Bus Balancing and Optimization on Compaq ProLiant Servers, March, 1998 – Doc ID ECG073/0398.*
- *Where Do I Plug the Cable? Solving the Logical-Physical Slot Numbering Problem, December 1996 – Doc ID 209A/1296.*
- *Deploying PCI Hot Plug on Compaq® Servers in a Microsoft® Windows NT® Environment, July 1997 - Doc ID 064A/0797.*

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Notice

Executive Overview

The term Peripheral Component Interconnect, commonly known as PCI, refers to the bus architecture standard. The PCI bus technology has become an industry standard; today's servers provide a large number of expansion slots and can be populated with a greater number of PCI disk and network controllers. PCI buses provide fast access between controllers and/or system memory and the host processor. PCI buses offer a significant performance advantage over EISA buses.

The PCI Special Interest Group (SIG) is an unincorporated association of members of the microcomputer industry set up for the purpose of monitoring and enhancing the development of the PCI architecture. The PCI Steering Committee is a group of nine companies that oversees SIG activities and reviews formal recommendations for changes to PCI Specification(s). Compaq is a member of the SIG Steering Committee and actively proposes and contributes new design functions for future revisions to the PCI Specification.

Later in this document, examples are provided in two test scenarios, illustrating what happens to PCI bus numbering when configuration changes occur.

PCI bus technology development continues to advance at a rapid pace to meet customer's business requirements. Server technology includes equipment, such as the ProLiant 8000 with multiple PCI buses. The computing capabilities of these servers can be further expanded through PCI controllers and PCI bridged devices such as the Smart Array 4250ES Controller. Each PCI bus in the system is numbered by the PCI BIOS during system start up. Windows NT uses these numbers to identify bridged controllers. If controllers are added to an existing system, the PCI bus numbering might change. This change might affect the operation of your system.

This white paper provides information to help systems professionals understand how the PCI Specification addresses server bus numbering assignments. This document discusses:

- How the PCI BIOS detects and numbers PCI buses and bridges.

- What happens to PCI Bus numbering at each system start up.

- How adding or removing PCI devices might cause a renumbering of PCI buses.

- How Windows NT handles bus numbering in the Windows NT Registry.

- How to prevent PCI bus numbering mismatches from occurring.

This document contains several examples to demonstrate PCI bus numbering. After reading this document, you should be able to properly configure and/or reconfigure a Windows NT system when PCI bus numbers are reassigned with minimal interruption to the network.

PCI Bus Architecture Terminology

Table 1 lists some terms related to PCI Bus Architecture terminology. Some of the terminology defined in this table was referenced from *PCI System Architecture, Third Edition, MindShare, Inc. Tom Shanley and Don Anderson. (November, 1995.)*

Table 1. PCI bus architecture standard terms

Bridge	Bridge is the device, providing connectivity between two independent buses.
Bus Number	Bus number is a number in the range 0…255 that uniquely selects a PCI bus.
Device ID	Device ID is a number in the range 0…31 that uniquely selects a device on a PCI bus.
Downstream	When a transaction is initiated and is passed through one or more PCI-to-PCI bridges flowing away from the host processor, it is said to be moving downstream.
Dual-Peer PCI Bus	A system architecture providing high-bandwidth I/0 because two buses can operate simultaneously (i.e., in parallel) is called a dual-peer-PCI bus.
Highly Parallel Architecture	A system architecture using dual memory controllers, dual-peer-PCI buses to deliver optimized multiprocessing support to deliver increased system throughput and increased system performance when compared to traditional x86-based designs is said to be highly parallel.
PCI	Peripheral Component Interconnect refers to a bus based on the PCI Local Bus Specification, through which industry-standard peripheral controllers connect to computer systems.
PCI BIOS	PCI BIOS functions provides a software interface to the hardware used to implement a PCI based system.
PCI Bridge	The device that provides the bridge between two independent buses. PCI bridges can reside on the system and can reside on controllers. PCI bridges help with signal integrity and allow more devices to be added per system.
PCI-to-PCI Bridge	PCI-to-PCI bridge is a system architecture where an additional PCI bus is bridged off another PCI bus (i.e., in series).
Peer-to-Peer PCI Buses	PCI buses that occupy the same ranking in the PCI bus hierarchy (with respect to the host bus) are referred to as Peer PCI buses.
Primary Bus	The PCI bus closest to the host processor that is connected to one side of the inter-bus bridge is the Primary Bus (numbering always starts at 0).
Secondary Bus	The PCI bus detected after the Primary Bus is called the Secondary Bus.
Tertiary Bus	The Tertiary bus resides furthest from host processor that is connected to one side of the inter-bus bridge.
Triple-Peer PCI Bus	System architecture operating with three PCI buses on a single server is referred to as a Triple-Peer PCI Bus.
Upstream	When a transaction is initiated and is passed through one or more PCI-to-PCI bridges flowing towards the host processor, it is said to be moving upstream.

PCI Hot Plug Terminology

Table 2 lists some terms related to PCI Hot Plug Terminology; however, this is not a complete list. The terms described here are those that relate to Hot Plug capabilities experienced in this document.

Table 2. PCI hot plug standard terms

*Hot Add	The ability to add existing PCI controllers and drivers to next generation controllers and drivers while a system is running, without shutting down the system.
Hot Plug Aware	Indicates that a piece of software, such as a device driver, can take advantage of the PCI Hot Plug capabilities of a system.
Hot Plug Slot	A PCI slot capable of being powered down without interfering with the other slots in the system, and without shutting the system down.
Hot Replacement	The ability to remove PCI controllers from a system while the system is running and replace them with equivalent PCI controllers, without removing power to the server and without reconfiguring or reloading software support.
*Hot Upgrade	The ability to upgrade existing PCI controllers and drivers to next generation controllers and drivers while a system is running, without shutting down the system.
PCI Hot Plug	The ability to physically insert or remove industry-standard PCI adapters while the system is running without disrupting the operation of other devices in the system.

 * Not available in initial release of PCI Hot Plug technology for Windows NT

PCI System Overview

This section reviews some of the basics of buses including PCI architecture and bridged controllers, PCI BIOS, PCI bus numbering, PCI BIOS discovery, and configuration changes to the bus numbering.

PCI Architecture and Bridged Controllers

There are four primary bus expansion schemes for PCI systems, namely the PCI-to-PCI bridge architecture, Dual-Peer PCI Bus architecture (see Figure 1), Highly-Parallel Bus architecture (see Figure 2), and Triple-Peer PCI Bus architecture (see Figure 3). The Compaq servers discussed in this white paper and used in the Integration Lab testing include these PCI architecture system designs. Refer to the "Compaq Server and Option Hardware" section of this white paper for more information.
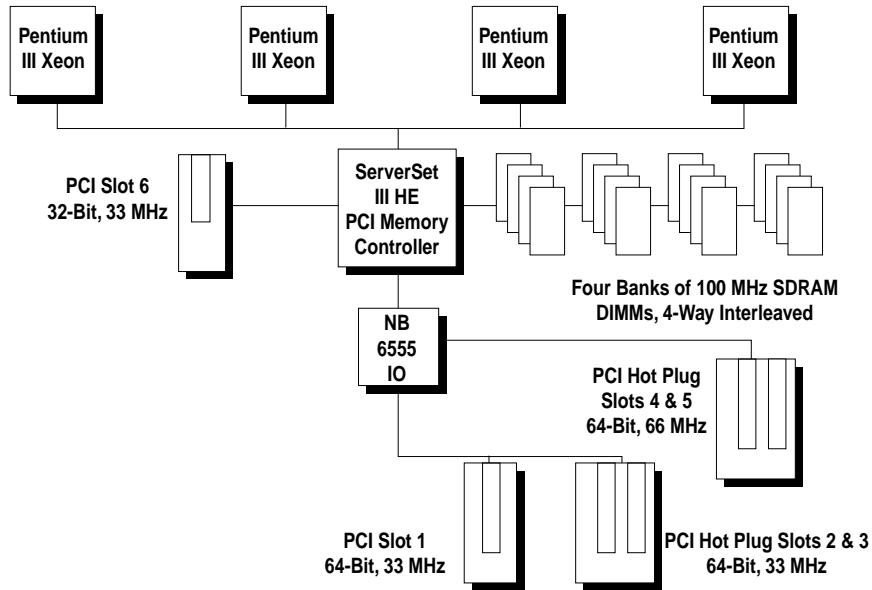
Figure 1.   Dual-peer PCI bus architecture in the ProLiant DL580
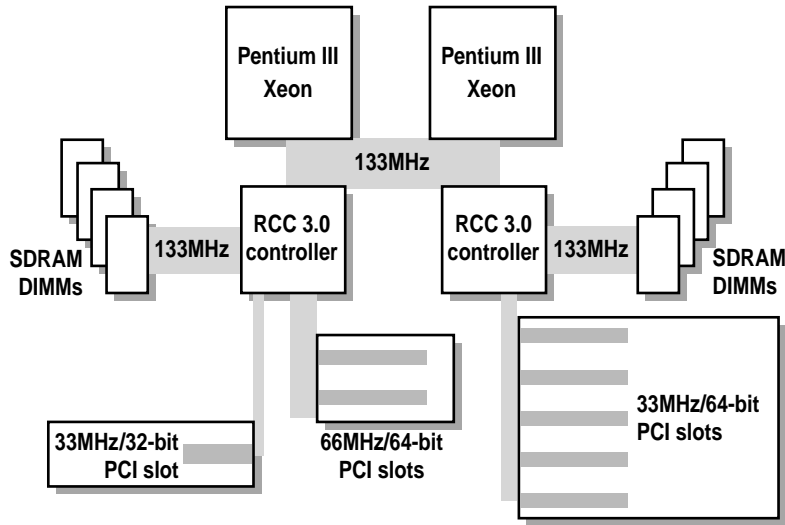
Figure 2.   Highly parallel PCI bus architecture in the ProLiant ML530
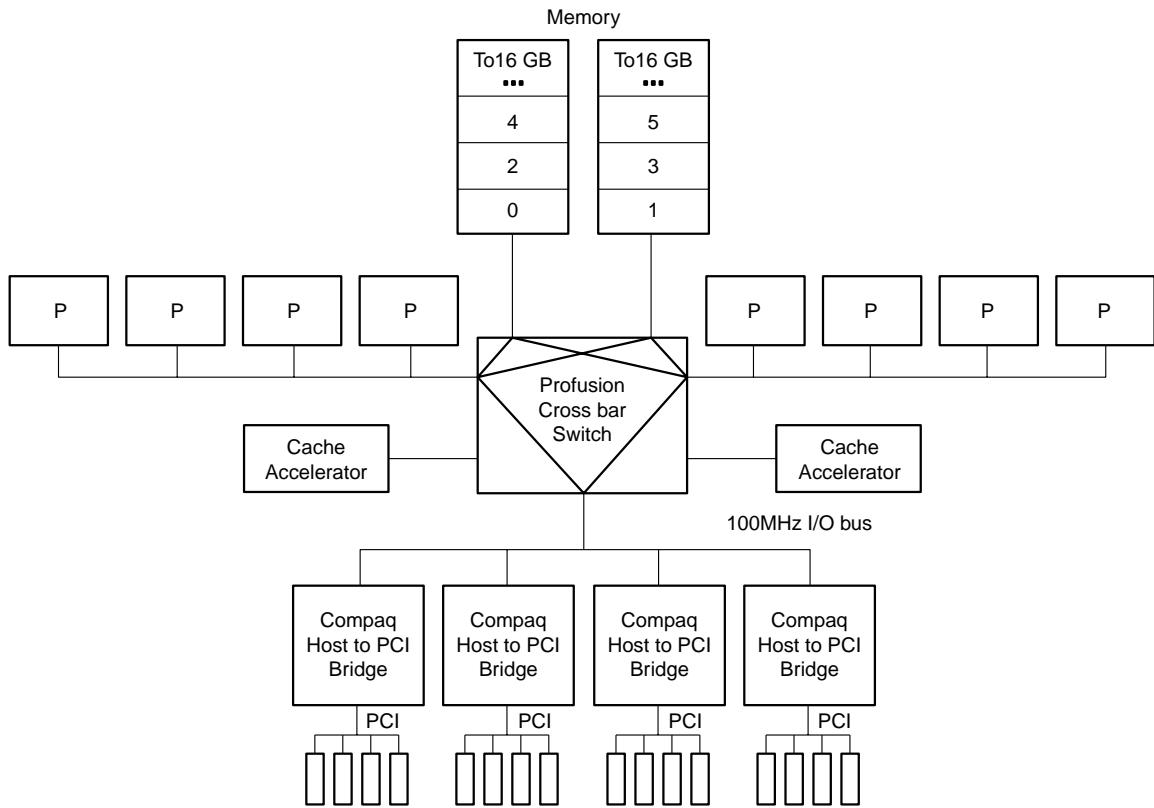
Figure 3.   Triple-peer PCI bus architecture in the ProLiant 8000

PCI bridges are not limited to the computer system; controllers can include them also. Hardware manufactures such as Compaq include PCI bridges on controllers to help with signal integrity, enabling more devices to be added per system. Data transfers from the host bus, through the primary PCI bus, through the PCI-to-PCI bridge on the controller, and finally to the PCI device. For example, an intelligent device such as a Smart Array 4250ES Controller contains a PCI bridge.

PCI BIOS

The PCI BIOS specification defines the rules regarding implementation of the PCI BIOS and the software that it calls. The PCI BIOS supplies services to the hardware platform, such as determining the range of PCI buses present in the system and searching for all instances of a specific PCI device. The PCI BIOS for each hardware manufacturer is platform-specific. The operating system, application programs, and device drivers do not directly access the PCI configuration area. On Compaq servers you can review system configuration information by accessing the Compaq System Configuration Utility during system startup before the operating system initialization (by pressing **F10**). The System Configuration Utility may be installed on a server with the Compaq SmartStart and Support Software CD or from a diskette to update the server configuration.

PCI Bus Numbering

At startup time, the PCI BIOS is aware only of the existence of PCI bus 0, the first bus number detected on the Primary PCI Bus. The PCI BIOS assigns numbers to each PCI bus and bridge it detects during system initialization. PCI bus numbers reassign each time the system starts and the discovery process begins again. Each PCI device receives the same PCI bus number if no changes have been made.

Each time the server restarts the PCI BIOS must walk the base PCI bus (starting at bus 0), subsequent bridges, and bridged devices to search and identify other PCI buses as if it were the first time. Each time the PCI BIOS discovers another PCI bus after a physical configuration change is made, it increments the bus number and continues to walk the bus until all other buses are discovered.

As it discovers each bus and/or bridge, the PCI BIOS:

- Records each unique bus number

- Associates the bus number to a bus or bridged PCI device

When the System Configuration Utility runs it builds a picture of the bus "tree" that represents the overall system topology. The System Configuration Utility displays the slot and bus number assignment for each PCI device in the server. Since controllers are physically installed in numbered slots, the PCI BIOS does not detect the numbers assigned to the slots, only the PCI devices installed in the slots. Systems professionals typically use slot numbers to identify and record the physical placement of controllers when configuring network systems. This document should help you predict how the PCI BIOS assigns and/or reassign bus numbers and how to associate these assignments to the physical slot numbers. Slot number assignments remain constant with a controller for as long as the controller is installed in a particular slot.

PCI BIOS Discovery

The following examples illustrate the PCI BIOS discovery and bus number assignment process for PCI buses, non-bridged controllers, and bridged controllers. The actual discovery process includes other components not shown here that reside on the PCI bus, such as video or embedded SCSI devices. However, this document omits these other components to simplify the example.

PCI Bus numbering is determined by the *order of detection* of each PCI bus discovered in a server configuration. The manufacturer defines the detection order for each server. Refer to "Table 11. PCI Bus Number Order of Detection Matrix" for Compaq ProLiant servers.

IMPORTANT: PCI Bus numbers are assigned in "device detection order," not by slot numbering.

Bus numbers are assigned during bus initialization according to predefined hardware designators. The bus numbers may not appear to follow a set increment and some numbers may be skipped. However, by this method, these hardware designators prevent overlays in bus numbering from occurring.

Dual-Peer PCI Bus – The Compaq ProLiant ML350 and DL580 servers are examples of the dual-peer PCI architecture. The PCI BIOS begins the discovery process at the Host Bus. When it detects the primary bus, it assigns bus 0 to it. The PCI BIOS then looks for PCI controllers in slots on the Primary Bus. PCI controllers detected without bridged PCI buses are assigned bus 0, the number of the bus in which it is seated. However, if the PCI Bios detects a bridged PCI device, it increments the bus number to 1 and assigns that bus number to the PCI bus detected on the bridged controller. (The next PCI bus detected is assigned a bus number according to the hardware designation for that system). This discovery process continues until all PCI controllers and controllers with bridged buses on the Primary Bus are detected. The PCI BIOS then continues the discovery process on the Secondary Bus until all PCI buses are detected.

The diagram in Table 3 shows an example of the discovery process. Table 3 does not represent all the PCI slots and bus assignment possibilities, it depicts snapshot of what occurs when controllers are loaded in the server.

Table 3. **Example of PCI bus number detection order for the ProLiant DL580 (a dual-peer system)**

ProLiant DL580 PCI Server Architecture PCI BIOS Discovery Process	Controller Bus Detection Order	Bus Number Assignment
⬇ Host Bus		
↘ Primary PCI Bus	First	0
⬇ Slot 5 – Empty	Second	0
⬇ Slot 6 – Empty	Third	0
↘ Secondary PCI Bus	Fourth	4
⬇ Slot 1 – Smart Array 4200 Controller	Fifth	5
⬇ Slot 2 – NC3131 Fast Ethernet NIC	Sixth	6
⬇ Slot 3 – NC3131 Fast Ethernet NIC	Seventh	7
⬇ Slot 4 – NC3131 Fast Ethernet NIC	Eighth	8

End of bus discovery

As indicated in Table 3, the order of detection on the ProLiant DL580 server is Primary Host-to-PCI Bridge, followed by PCI controllers and bridged controllers on the Primary Bus in slots beginning at 5 and ending at slot 6. The bus discovery process continues with the Secondary Host-to-PCI Bridge, followed by PCI controllers and bridged controllers in slots beginning at 1, 2, 3, and ending at slot 4.

Highly Parallel PCI Bus – The Compaq ProLiant ML530 provides an example of highly parallel PCI architecture. This architecture uses dual memory controllers, dual-peer-PCI buses to deliver optimized multiprocessing support to deliver increased system throughput, and increased system performance when compared to traditional x86-based designs.

Triple-Peer PCI Bus – The Compaq ProLiant 8000 is an example of the triple-peer PCI architecture. The PCI BIOS begins the discovery process at the Host Bus. In a triple-peer PCI bus architecture the Primary Bus is the first bus detected and it is assigned bus 0. The PCI BIOS then looks for PCI controllers in slots on the Primary Bus. PCI controllers detected without bridged PCI buses are assigned bus 0, which is the number of the bus it is seated in. However, if a PCI controller is detected with a bridged PCI device, the PCI BIOS increments the bus number to 1 and assigns that bus number to the PCI bus detected on the bridged controller. This discovery process continues until all PCI controllers and controllers with bridged buses on the Primary Bus are detected. The PCI BIOS then continues the discovery process on the Secondary Bus until all PCI buses are detected, and then on to the Tertiary Bus until all PCI buses are detected.

The diagram in Table 4 is an example of the discovery process.

Table 4. **Example of PCI bus number order of detection for ProLiant 8000 (a triple-peer system)**

ProLiant 8000 PCI Server Architecture PCI BIOS Discovery Process	Controller Bus Detection Order	Bus Number Assignment
⬇ Host Bus		
↘ Primary PCI Bus	First	0
⬇ PCI Slot 1 – Pri Bus Empty	Second	0
⬇ PCI Slot 2 – Pri Bus Empty	Third	0
⬇ PCI Slot 3 – Pri Bus Empty	Fourth	0
⬇ PCI Slot 4 – Pri Bus Empty	Fifth	0
↘ Secondary PCI Bus	Sixth	6
⬇ PCI Slot 5 – Sec Bus Empty	Seventh	6
⬇ PCI Slot 6 – Sec Bus Empty	Eighth	6
⬇ PCI Slot 7 – Sec Bus PCI Controller (no bridge)	Ninth	6
⬇ PCI Slot 8 – Sec Bus PCI Controller (integrated PCI bridge)	Tenth	7
⬇ PCI Slot 9 – Sec Bus Empty	Tenth	6
↘ Tertiary PCI Bus	Eleventh	13
⬇ PCI Slot 10 – Ter Bus PCI Controller (no bridge)	Twelfth	13
⬇ PCI Slot 11 – Ter Bus PCI Controller (integrated PCI bridge)	Thirteenth	14

**End of bus
discovery**

The "Additional Troubleshooting Tips" section of this document contains a matrix titled "Table 11. PCI Bus Number Order of Detection Matrix". This matrix lists the PCI Bus detection order for several Compaq ProLiant servers.

In this scenario, PCI BIOS assigns the Primary Bus as bus 0. Since it detects no devices in the Primary Bus, the discovery process continues to the Secondary Bus, assigned bus 6. The first PCI controller detected downstream from the Secondary Bus does not contain a bridge, this controller is assigned bus 6, the same as the Secondary PCI bus. The discovery process continues with bus number assignments for other controllers on the Secondary Bus based on the order of detection. Once again, if the PCI controller is a bridged PCI device, the bus number increments, if the PCI controller is a non-bridged device then the controller is assigned the same number as the bus it is seated in. After detection on the Secondary Bus completes, the Tertiary PCI Bus is assigned the bus 13.

For example, the order of detection on the ProLiant 8000 is Primary Host-to-PCI Bridge, followed by PCI controllers and bridged controllers on the Primary Bus in slots beginning at 1, 2, 3 and ending at slot 4. The bus discovery process continues with the Secondary Host-to-PCI Bridge, followed by PCI controllers and bridged controllers in slots beginning at 5, 6, 7, 8, and ending at slot 9. Then, the process moves forward to the Tertiary Host-to-PCI Bridge, followed by PCI controllers and bridges controllers in slots beginning at 10 and ending at slot 11.

Configuration Changes

Bus number assignments for controllers with bridged devices are assigned to the PCI bus on the controller.

From time to time, network administrators add disk and network controllers to existing configurations to address the requirements of growing server networks. Adding a bridged controller earlier in the discovery order than other existing controllers can change the PCI bus number assignment of all bridged PCI controllers detected after it. Each subsequent controller in the discovery process (containing a bridged PCI bus) receives an incremented bus number assignment, regardless of whether it is new or it was previously configured.

The PCI BIOS assigns resources at power-up, the server must be restarted before the PCI BIOS can assign PCI bus numbers to each bus discovered in the new configuration. The PCI BIOS assigns PCI bus numbers to each PCI device in the order of discovery without any concern for prior bus assignments or the physical slot location. Several bus-numbering scenarios included in this white paper demonstrate how the PCI BIOS discovers PCI buses and assigns numbers.

Windows NT and PCI Bus Numbering

During the initial installation of Windows NT, all network controllers in the server automatically add to the registry along with the bus number assignment. This is the only time that Windows NT automatically adds the PCI bus numbers in the registry. If no physical configuration changes are made to the system in the future, Windows NT continues to detect the controllers after future system restarts.

IMPORTANT: During the development of Microsoft Windows 2000, Compaq and Microsoft worked closely together effectively implementing Windows 2000 on Compaq hardware. Through this partnership, device detection improved, eliminating PCI bus numbering issues in the Windows 2000 environment. Windows 2000 checks and resets registry settings automatically, unlike its predecessor that does not reset the registry settings after discovering unbound devices.

PCI Bus Numbering and Network Controllers

When you modify a server by adding a new controller, removing a controller, or moving a controller to a different slot, Windows NT might not detect the change in the server configuration. Configuration changes only occur when you insert or remove a bridged device. The PCI BIOS renumbers PCI bus numbers assigned to PCI buses and PCI bridged devices during the discovery process, based on the new configuration. Windows NT does not automatically check for new bus number assignments. Windows NT retains the original controller slot number and bus number assignments in its registry after the server restarts. However, the bus number assignments in the Windows NT registry can be updated using the appropriate network configuration tool for your controllers. The Compaq TLAN Teaming and Configuration Utility supports Compaq NetFlex-3 and Netelligent Controllers (see Appendix C for usage information),

where as, the Compaq Network Teaming and Configuration Utility supports Compaq 10/100 and Gigabit NICs, discussed in this document.

Note: When configuration changes are necessary due to server maintenance or upgrade, Compaq recommends that you plan your changes carefully, document all original settings and bindings, and backup the system.

Physical controller modifications made after the initial configuration can adversely affect the original bindings. To make the controller functional again, you must reset the controller and device driver bindings. Network controllers must bind to device drivers to be functional and provide connectivity on a network. System Administrators unaware that new bus number assignments were made after a configuration change might falsely believe that the hardware is broken.

Compaq and Microsoft provide several utilities you can use to reset device driver and controller bindings. As long as the System Administrator knows bus numbers are assigned in a server, the Windows NT registry can be reset with minimal effort. See the section titled "PCI Test Configurations with ProLiant Servers" in this document.

Disk Renumbering

Disk reordering can complicate an administrator's ability to identify what a particular disk volume contains when the numbers change in Disk Administrator. However, disk number reordering does not affect the contents of the disk volume.

The Windows NT Disk Administrator located under Start→Programs→Administrative Tools (Common) contains a graphical tool provided with the operating system to manage disk drives. This tool allows Disk Administrators to display and track disk devices. Windows NT lists drives and volumes in this utility in the order discovered at system startup. Each drive detected during discovery shows in the Disk Administrator with a disk number (starting at 0). The hard drive that boots the system must have one partition designated as the active partition and that loads as Disk 0. Compaq recommends running the Disk Administrator after completing a Windows NT installation to ensure that the boot drive receives a signature properly (Drive C:) and locks the drive letter to the partition.

The Compaq SCSI and Array Disk Controllers have a Windows NT Registry entry used to determine disk controller-loading order. If disk numbers/drive letters become reordered because of a changed drive load order, the operation of the applications on the disk should not be affected. When you create a partition on a disk drive; Windows NT Disk Administrator should be run to permanently lock the drive letter to the partition even if Drive C: is the only disk in the system.

In simple configurations, identifying contents on a particular drive or volume might not be an issue. In more complex configurations consisting of multiple drives and volumes, the order in which the drives/volumes are listed can change when a physical modification is made to the disk configuration. As mentioned earlier, Windows NT Disk Administrator lists drives and volumes in the order they are discovered.

Disk ordering in a simple example:

Order of detection (Before Change)	Drive Letter and Label
Disk 0	C: NT OS
Disk 1	D: ACCT files

Add two more drives to the system and the order of detection changes:

Order of detection (After Change)	Drive Letter and Label	
Disk 0	C: NT OS	**Active System Partition**
Disk 1	Unknown (not formatted)	**New**
Disk 2	E: ENG files	**New**
Disk 3	D: ACCT files	**Disk order changed**

Windows NT orders disk volumes in the order of discovery at boot time. Adding more drives to an already configured system can change the order of detection. Descriptively labeling the disk volumes using the Disk Administrator can eliminate frustration and prevent unnecessary confusion identifying the contents of a disk volume. Labeling the volume ensures that you can easily identify its content.

Hardware, Software, and Configuration Tools

This section identifies the Compaq servers and option hardware used to create test scenarios in the Compaq Windows NT Integration Lab. All tests ran under the Windows NT 4.0 operating system. In addition to the operating system, several Compaq utilities and Windows NT administration tools were used to aid in the testing process. Testing included slot identification, bus number assignments, disk number assignments, and resetting the configuration after a system modification.

Compaq Servers and Option Hardware

This section provides a brief description of the servers and option hardware used to test PCI bus numbering and slot configurations for this document.

Compaq Servers

This white paper details the PCI bus numbering scheme of five Compaq ProLiant server models.

Note: The features discussed in this section should not be considered a complete description for any of the server or option hardware. Refer to the specification for each product to learn more about the complete feature set. This information is available on the Compaq website at http://www.compaq.com/products/servers.

The ProLiant ML350 and ProLiant DL580 contain the dual-peer PCI bus architecture. Two other servers, the ProLiant DL380 and the ProLiant 530, have a highly parallel architecture, whereas, the ProLiant 8000 has a triple-peer PCI bus architecture as documented in Configuration B.

The ProLiant DL580 results are described in Configuration A, and the ProLiant ML530 server's PCI bus numbering results are detailed in Configuration C.

The PCI BIOS discovery process for the ProLiant ML350 and ProLiant DL380 servers is available in the "PCI Bus Number Order of Detection Matrix" provided in this document.

ProLiant 8000

The ProLiant 8000 has 11 PCI slots: ten 64-Bit slots and one 32-Bit PCI slot.

Primary Bus:

Slot 1 is the first PCI slot detected in this server configuration. Bus numbering starts here and continues to slots 2, 3, and 4.

Secondary Bus:

Bus numbering continues down to slots 5, 6, 7, 8, and 9.

Tertiary Bus:

Then, bus numbering completes after reaching slots 10 and 11.
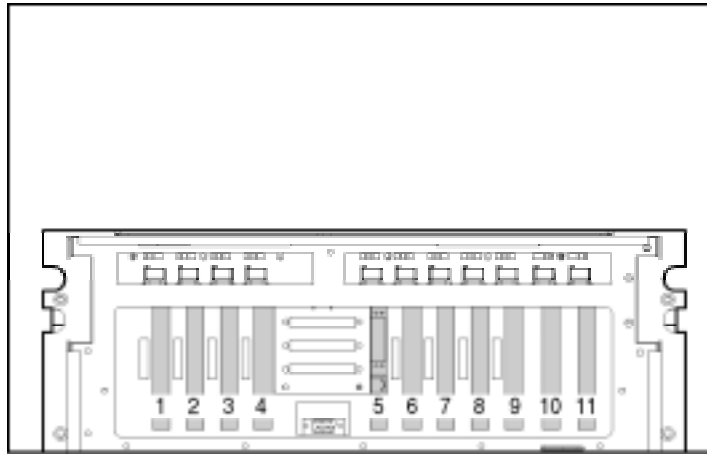
Figure 4. Slot view of the ProLiant 8000

ProLiant ML530

ProLiant ML530 contains a highly parallel bus and has 8 PCI slots: two 64-Bit 66MHz slots, five 64-Bit 33MHz slots, and one 32-Bit 33MHz slot.

Primary Bus:

Slot 1 comprises the Primary Bus.

Secondary Bus:

Bus numbering continues down level to slots 7 and 8.

Tertiary Bus:

Bus numbering continues down level to slots 6, 4, 3, and 2, completing after assigning a bus number to slot 5.
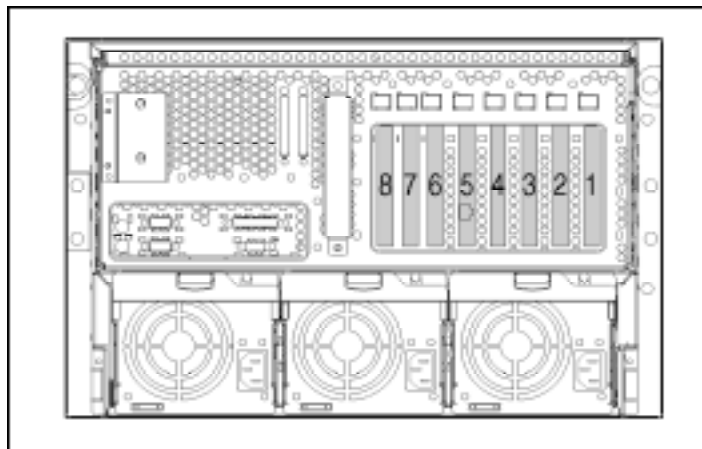
Figure 5. Slot view of the ProLiant ML530

ProLiant ML350

ProLiant ML350 is a dual-peer bus and has 7 PCI slots: two 64-Bit 3V slots, four 32-Bit slots, and one Non-Shared ISA slot.

Primary Bus:

Bus numbering begins on slot 1 and continues to slots 4, 5, and 6.

Secondary Bus:

Slots 2 and 3 comprise the Secondary Bus and complete the bus numbering in this server configuration.
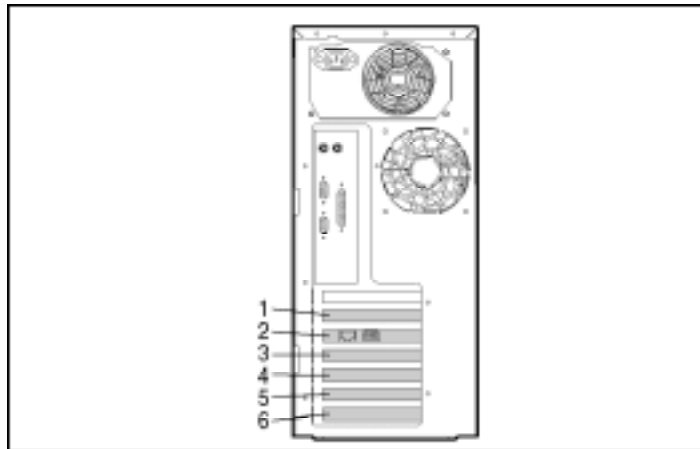
Figure 6. Slot view of the ProLiant ML350

ProLiant DL580

ProLiant DL580 is a dual-peer bus and is comprised of 6 PCI slots: two 64-Bit/66MHz slots, three 64-Bit/33MHz slots, and one 32-Bit/33MHz slot.

Primary Bus:

The Primary Bus completes bus numbering after assignment to slots 5 and 6.

Secondary Bus:

Bus numbering begins with slot 1 and continues to 2, 3, and 4.
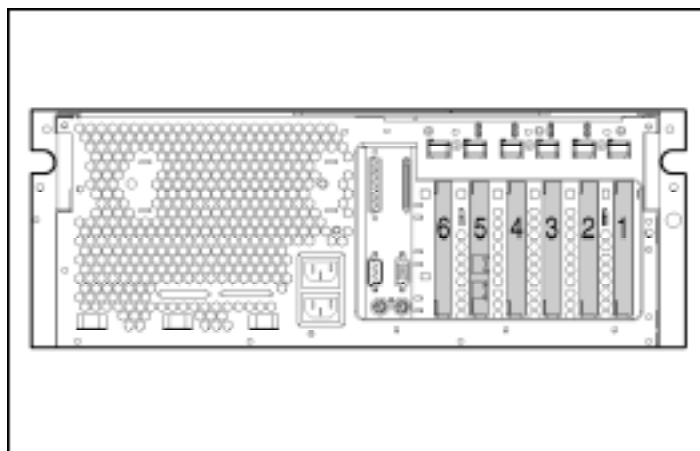
Figure 7. Slot view of ProLiant DL580

ProLiant DL380

ProLiant DL380 contains a highly parallel bus and has 4 PCI slots: three 64-Bit slots and one 32-Bit slot.
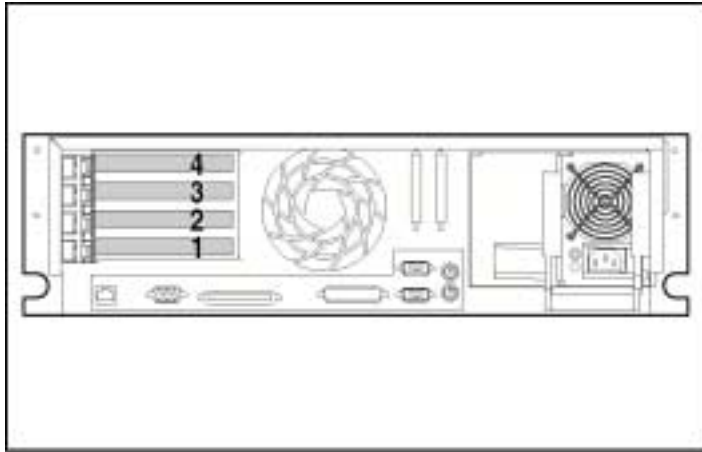
Primary Bus:

Slot 1 is the only slot on the Primary Bus.

Secondary Bus:

Slots 2, 3, and 4 complete bus numbering on this server configuration.

Figure 8. Slot view of the ProLiant DL380

Option Hardware

The following list identifies the types of Compaq controllers that are categorized as either PCI bridged or non-bridged.

PCI Bridged Controllers	Non-Bridged Controllers
All Smart Array Controllers	All Fast, Wide, and Ultra SCSI Controllers
All SMART-2 Disk Controllers	Most Video Controllers
Compaq Fast Ethernet Controllers and Modules (excluding Single Port)	NC3123 Fast Ethernet Network Adapter PCI 10/100 Wake-on-LAN
All Compaq Gigabit Controllers and Modules	NetFlex-3 and Netelligent Controllers (excluding Dual Port)
Netelligent Dual 10/100 TX PCI UTP Controller	

Network Interface Controllers

The controllers and modules containing Intel technology and supported by a Compaq developed device driver deliver fast data throughput and low processor utilization. The Compaq Ethernet, Fast Ethernet, and Gigabit controllers contain the Intel chip set. Visit the Compaq website for a complete list of supported controllers at http://www.compaq.com/products/networking/nics/.

Disk Controllers

The Smart Array Family includes the following controllers:

- Smart Array 221 Controller

- Smart Array 431 Controller

- Smart Array 3100ES Controller

- Smart Array 3200 Controller

- Smart Array 4200 Controller

- Smart Array 4250ES Controller

- Integrated Smart Array Controller

- RAID LC2 Controller

Visit the Compaq website for a complete list of these controllers
http://www.compaq.com/products/servers/storage.

Planning a PCI System Configuration

Modifying a multi-controller configuration and understanding what happens to specific physical devices can be confusing in a PCI-based network server. Spending a little planning time up front to become familiar with the server slot and bus configuration can prevent you from having to take unnecessary time later trying to troubleshoot configuration mismatches. In many cases, it completely prevents mismatches from occurring.

Note: PCI bus number assignment changes only if PCI bridge devices are added or removed from the system.

Compaq recommends adding controllers to slots in the order in which the slots appear on the bus. Following this recommendation prevents the occurrence of the scenarios discussed in the "PCI Test Configurations with ProLiant Servers" section of this paper. Such occurrences are most likely when controllers are added to an existing server configuration out of order, leaving vacancies between slots that reside on the same bus.

Before Modifying an Existing System

Complete a thorough planning session to understand possible considerations and anticipate unexpected issues. Be sure to have a backup plan so you can return to your original configuration if necessary.

Because bus renumbering is likely to occur when controllers are added or removed in a PCI configuration, Compaq recommends that you perform the following steps:

- Backup the server registry and all data so that you can return to the original configuration, if necessary.

- Update the Emergency Repair Disk so that you can use it to restore current system settings.

- Run the System Configuration Utility, from the System boot partition, and print out the log that the utility generates. This log identifies slot numbers and bus number assignments.

- Log important network settings such as, protocols, IP addresses, frame types, etc.

When loading Disk Administrator you will automatically be notified, if a drive does not have a signature.

- Label the disk drives/volumes using the Windows NT Disk Administrator. Drive letters remain the same, but disk number assignment might change, including labels on disk helps identification.

- Run Disk Administrator to verify that additional drives have received a signature from Windows NT.

- Verify you have the necessary Windows NT CDs and the Compaq Support Paq for Microsoft Windows NT 4.0 to update drivers, if necessary. This information will be essential should you need to return to the original configuration.

Planning the New Configuration

The next part of the plan involves identifying the best method to update the original configuration. Armed with the knowledge that PCI slot number and bus number assignments are affected when controllers are added or removed will help you integrate new hardware into an existing server configuration with minimal disruption and downtime.

You will also want to answer the following questions, before making modifications:

- Will the network controllers be standalone or set up as a redundant pair? Decide which slot(s) to use for the NIC(s).

- What slots will be used for the disk controller(s)? Does the configuration include external storage?

- Is the system load balanced across the buses to provide the optimal system performance?

- Does the controller(s) have a bridge? Controllers that contain bridges will be assigned a PCI bus number which increments the bus numbering assignment of each subsequent PCI bridged controller detected.

Reviewing these questions ahead of time will help you with the decision making process; each computing environment differs and the responses to these questions will not be the same for every configuration. You, as the network administrator, must determine the best solution for your computing needs.

Step-By-Step Review

The Compaq Array Configuration Utility can also be installed within the Windows NT GUI after the operating system is installed.

Before beginning this process, Compaq recommends that you review your configuration requirements and be prepared to answers the questions noted earlier in the "Planning the New Configuration" section.

As with any installation:

- Verify all network and disk controllers included in the configuration are seated properly in the slots designated during the planning stage, before the server is powered on.

- Gather all necessary operating system and support software.

- Load the Compaq Systems Configuration software on the server and install it on the system partition of the hard drive. We used the following Compaq Systems Configuration software testing and tracking tools to develop this white paper:

  - System Configuration Utility - to configure the hardware and to view the slot and bus number assignments before launching the Windows NT operating system.

  - Drive Array Configuration Utility - to create disk arrays across multiple drives.

  Note: Installing the System Configuration utilities on the server provides an easy way to configure and verify hardware installations and modifications to the system in the future as needed.

- Load the Compaq Support Paq (CSP) for Microsoft Windows NT 4.0 to ensure the system is running with the latest driver enhancements. In addition to driver enhancements, the Compaq Support Paq installs several important support utilities. The Compaq Support Paq runs a detection process and identifies the software and utilities applicable to the installation.

PCI Test Configurations with ProLiant Servers

The following scenarios were tested in the Compaq Integration Lab. The scenarios demonstrate how the PCI BIOS assigns the bus numbers and then reassigns the bus numbers after configuration modifications. The following examples demonstrate the step-by-step changes that occur:

Configurations A and B were also performed using retired Compaq ProLiant servers. These results are detailed in Appendix A.

- Configuration A: Test 1 – Initial Configuration and Test 2 – Adding a Device.

- Configuration B: Test 1 – Initial Configuration and Test 2 – Addition of Two Controllers.

- Configuration C: Test 1 – Initial Configuration and Test 2 – Removing and Adding NICs Out of Slot Order.

By understanding what configuration changes occur in the test scenarios described in this section, you can better comprehend how PCI Bus numbers reassign when configuration changes occur in your server. "Table 11. PCI Bus Number Order of Detection Matrix" included in this document identifies the Controller Discovery Order for each of these servers and several others.

Configuration A, ProLiant ML530 (highly parallel architecture), a two configuration scenario: This scenario walks through a simple Windows NT configuration and shows how the bus numbers change when you add a new controller to the server. Two tables with a side bar description of what the PCI BIOS does during the discovery process illustrate the configurations.

Configuration B, ProLiant 8000 (triple-peer architecture), a more complex two configuration scenario: We modified the server to include additional disk and network controllers. Two tables with a side bar description of what the PCI BIOS does during the discovery process illustrate the configurations.

Configuration C, ProLiant DL580 (dual-peer architecture), a more complex scenario: This demonstrates the slot ordering difference when additional disk and network controllers are inserted out of order in the configuration. Two tables with a side bar description of what the PCI BIOS does during the discovery process illustrate the configurations.

Configuration A, ProLiant ML530

All the controllers included in this configuration were installed in the server before Windows NT was loaded on the system. Windows NT detected network controllers in the original configuration during the installation process. However, when the configuration is modified in Test 2, PCI bus renumbering does occur.

Configuration A: Test 1 – Initial Configuration

This bus number and controller discovery test was performed on a simple configuration in a dual-peer PCI ProLiant ML530 server. This configuration is described as simple because it contains one non-bridged PCI network controller and one bridged PCI network controller.

Note: Even though PCI bus numbers assign during every boot process, the number remains exactly the same as long as the configuration remains the same.

Table 5. PCI BIOS bus detection in a ProLiant ML530–before adding a bridged controller

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type – Test 1	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (O)**	Host to PCI Bridge	**Bus 0**	The PCI BIOS discovers the Primary Bus and assigns it bus 0.
2nd	Slot 1	Empty	N/A	Discovery process continues to PCI slot 1. No PCI controller detected, no bus number assigned.
3rd	**Secondary Bus (2)**	Host to PCI Bridge	**Bus 2**	The PCI BIOS discovers the Secondary Bus and increments the bus number to 2. Discovery process continues to PCI slot 7. No PCI controller detected, no bus number assigned.
4th	Slot 7	Empty	N/A	
5th	Slot 8	Empty	N/A	Discovery process continues to PCI slot 8. No PCI controller detected, no bus number assigned.
6th	**Tertiary Bus (5)**	Host to PCI Bridge	**Bus 5**	The PCI BIOS discovers the Tertiary Bus and increments the bus number to 5.
7th	Slot 6	Empty	N/A	Discovery process continues to PCI slot 6. No PCI controller detected, no bus number assigned.
8th	Slot 4	Empty	N/A	Discovery process continues to PCI slot 4. No PCI controller detected, no bus number assigned.
9th	Slot 3	Empty	N/A	Discovery process continues to PCI slot 3. No PCI controller detected, no bus number assigned.
10th	Slot 2	Empty	N/A	Discovery process continues to PCI slot 2. No PCI controller detected, no bus number assigned.
11th	Slot 5	NC3132 (non-bridged)	Bus 5	PCI BIOS detects a NIC (no PCI bridge) in slot 5, it is assigned the same bus number as the PCI Bus where it resides, and is the first controller detected by the PCI BIOS.

Reviewing the Test 1 Configuration

In Test 1, the PCI BIOS begins the discovery process by identifying buses on the Primary PCI Bus, then continues to the Secondary PCI Bus looking for PCI buses and or bridges, and completes after reaching the last slot on the Tertiary PCI bus. As each bus is detected it is assigned a bus number starting at bus 0, the PCI BIOS then assigns bus numbers to the PCI controllers discovered on each bus. In this example, the controllers do not contain bridges. Therefore, they are assigned the same bus number as the bus on which they reside.

Note: Bus numbers (appear in boldface type in Table 5) are assigned during bus initialization according to predefined hardware designators. The bus numbers may not appear to follow a set increment and some numbers may be skipped. However, by this method, these hardware designators prevent overlays in bus numbering from occurring.

Configuration A – Test 2 – Adding a Device

The example in Table 6 illustrates the PCI BIOS discovery and bus number assignment process in the same ProLiant ML530 server. However, the configuration changes slightly by adding a bridged PCI network controller on the Tertiary Bus.

Table 6. PCI BIOS bus detection in a ProLiant ML530–after adding a bridged controller

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type – Test 1	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (O)**	Host to PCI Bridge	**Bus 0**	The PCI BIOS discovers the Primary Bus and assigns it bus 0.
2nd	Slot 1	Empty	N/A	Discovery process continues to PCI slot 1. No PCI controller detected, no bus number assigned.
3rd	**Secondary Bus (2)**	Host to PCI Bridge	**Bus 2**	The PCI BIOS discovers the Secondary Bus and increments the bus number to 2.
4th	Slot 7	Empty	N/A	Discovery process continues to PCI slot 7. No PCI controller detected, no bus number assigned.
5th	Slot 8	Empty	N/A	Discovery process continues to PCI slot 8. No PCI controller detected, no bus number assigned.
6th	**Tertiary Bus (5)**	Host to PCI Bridge	**Bus 5**	The PCI BIOS discovers the Tertiary Bus and increments the bus number to 5.
7th	Slot 6	NC3131	Bus 6	Discovery process continues to PCI slot 6, and detects a bridged NIC, incrementing the bus number by one to become bus 6.
8th	Slot 4	Empty	N/A	Discovery process continues to PCI slot 4. No PCI controller detected, no bus number assigned.
9th	Slot 3	Empty	N/A	Discovery process continues to PCI slot 3. No PCI controller detected, no bus number assigned.
10th	Slot 2	Empty	N/A	Discovery process continues to PCI slot 2. No PCI controller detected, no bus number assigned.
11th	Slot 5	NC3132 (non-bridged)	Bus 5	PCI BIOS detects a NIC (no PCI bridge) in slot 5, it is assigned the same bus number as the PCI Bus where it resides.

*Bus number is different than previous configuration

Reviewing the Test 2 Configuration

In Test 2, as in Test 1, the PCI BIOS begins the discovery process by identifying buses on the Primary PCI Bus, which is assigned bus 0. Slot 6 on the Tertiary Bus now contains a NC3131 Fast Ethernet NIC (a bridged controller), which increments the bus number assignment to bus 6. The network controller in slot 5 is also assigned bus 5 as it was before.

At this point, Windows NT is not aware that the bus number assignments have changed. The bindings for the network controller in slot 6 are no longer applicable and must be manually reset for this controller to function in the configuration again. Refer to the "Compaq Network and Teaming Configuration Utility" section in this document for instructions on how to reset the bindings.

Comparison of Test 1 to Test 2 - Configuration A

When you reboot the server and run the System Configuration utility to view the hardware configuration changes, it displays slot and bus number assignments. Test 2 data was recorded and compared to Test 1.

A side-by-side comparison of the slot configurations and bus numbers of each device in Test 1 to the slot configurations and bus numbers of each device in Test 2, illustrates what bus numbers were changed after modifications took place.

Slot	Type Controller	Test 1	Test 2	Bus Assignment
Slot 1	Empty			N/A
Slot 2	Empty			N/A
Slot 3	Empty			N/A
Slot 4	Empty			N/A
Slot 5	NC3123 (non-bridged)	✓	✓	Bus 5 – No Change
Slot 6	NC3131 (bridged)		✓	Bus 6 – New
Slot 7	Empty			N/A
Slot 8	Empty			N/A

Configuration B, ProLiant 8000

Configuration B included two installations tested on the ProLiant 8000. The test 1 server was set up as an original Window NT server configuration. All the controllers included in this configuration were installed in the server before Windows NT was loaded on the system. Because they were a part of the original configuration, Windows NT detected the network controllers during the installation process. However, when additional controllers are later added to the system in a modified configuration, PCI bus renumbering does occur. The information that follows in this section explains these changes as they occur and how you can easily modify Windows NT with several Compaq and Windows NT utilities.

The diagrams in Figure 9, illustrates the location of the expansion slots in the rear of the ProLiant 8000.
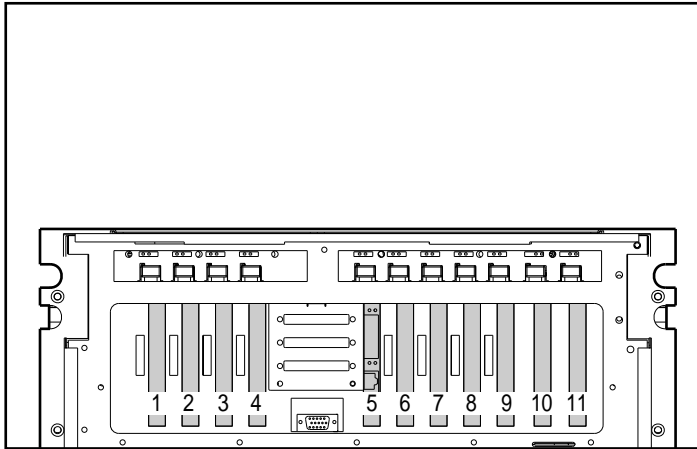
Figure 9. Location of expansion slots in the ProLiant 8000

Bus number assignments for controllers with bridged devices are assigned to the device on the controller.

Table 7 illustrates the relationship between slot numbers, controller installation, and PCI BIOS bus assignments in Configuration B–Test 1. This test includes several bridged controllers to demonstrate bus renumbering in a more complex configuration.

Table 7. Test 1 – PCI BIOS bus detection in the ProLiant 8000

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 1	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (O)**	Host to PCI Bridge	**Bus 0**	The PCI BIOS assigns 0 to the Primary Bus and continues downstream with the controller discovery.
2nd	Slot 1	Empty	N/A	Slots 1-4 are empty, no PCI bus number assignment.
3rd	Slot 2	Empty	N/A	
4th	Slot 3	Empty	N/A	
5th	Slot 4	Empty	N/A	
6th	**Secondary Bus (6)**	Host to PCI Bridge	**Bus 6**	The PCI BIOS discovers the Secondary Bus and assigns it bus number 6.
7th	Slot 5	NC3131	Bus 7	NIC in slot 5 contains a PCI bridge and the PCI BIOS increments the PCI bus number to 7.
8th	Slot 6	Empty	N/A	
9th	Slot 7	Empty	N/A	
10th	Slot 8	Empty	N/A	Slots 6-8 are empty, no PCI bus number assignment.
11th	**Tertiary Bus (13)**	Host to PCI Bridge	**Bus 13**	
12th	Slot 9	Empty	N/A	The PCI BIOS discovers the Tertiary Bus and assigns it bus number 13.
13th	Slot 10	Empty	N/A	Slots 9 and 10 are empty, no PCI bus number assignment.
14th	Slot 11	Smart Array 4250ES	Bus 14	Intelligent drive array controller with PCI bridge is detected in slot 11. The PCI BIOS increments the PCI number to bus 14 and assigns it to the bridge on the controller.

Reviewing the Test 1 Configuration – Initial Configuration

Configuration B−Test 1, illustrated in Table 7, provides an example of how the PCI BIOS discovers controller devices and assigns bus numbers during the discovery process. As the PCI BIOS moves through the bus detection order it looks for controller devices (not the slot numbers). In this example, the PCI BIOS begins at the Host Bus and moves downstream assigning bus numbers starting at bus 0 on the Primary Bus. In this scenario, no PCI devices reside on the Primary bus, so the discovery process continues to the Secondary Bus by assigning 6 as the bus

number. The NC3131 in slot 5, a bridged device, is discovered next. The PCI BIOS assigns bus 7 to the PCI bus on the bridged controller, the last PCI controller discovered on the Secondary Bus.

At this point, the PCI BIOS discovery process continues to the Tertiary Bus where it increments the bus assignment to 13. The Smart Array 4250ES Controller in slot 11 is assigned bus 14 since it is a bridged device.

Test 2 in Table 8 illustrates how bus assignments change when physical configuration changes occur in the server.

IMPORTANT: The controllers that our testing added to the server configuration were selected only to illustrate how bus renumbering occurs. Several different Smart Array and network controllers were included to demonstrate that they all respond to renumbering in the same manner. This is not meant to be a recommended configuration.

Table 8: Test 2 – PCI BIOS bus detection in the ProLiant 8000

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 2	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (O)**	Host to PCI Bridge	**Bus 0**	The PCI BIOS assigns 0 to the Primary Bus and continues downstream with the controller discovery.
2nd	Slot 1	Empty	N/A	Slot 1 is empty, no PCI bus number assignment.
3rd	Slot 2	NC3131	Bus 1	NIC in slot 2 contains a PCI bridge and the PCI BIOS increments the PCI bus number to 1.
4th	Slot 3	Empty	N/A	Slots 3 and 4 are empty, no PCI bus number assignment.
5th	Slot 4	Empty	N/A	
6th	**Secondary Bus (6)**	Host to PCI Bridge	**Bus 6**	The PCI BIOS discovers the Secondary Bus and assigns it bus number 6.
7th	Slot 5	NC3131	Bus 7	NIC in slot 5 contains a PCI bridge and the PCI BIOS increments the PCI bus number to 7.
8th	Slot 6	Empty	N/A	
9th	Slot 7	Empty	N/A	Slots 6-8 are empty, no PCI bus number assignment.
10th	Slot 8	Empty	N/A	
11th	**Tertiary Bus (13)**	Host to PCI Bridge	**Bus 13**	The PCI BIOS discovers the Tertiary Bus and assigns it bus number 13.
12th	Slot 9	Empty	N/A	Slot 9 is empty, no PCI bus number assignment.
13th	Slot 10	Smart Array 4250ES	Bus 14	Intelligent drive array controller with PCI bridge is detected in slot 10. The PCI BIOS increments the PCI number to bus 14 and assigns it to the bridge on the controller.
14th	Slot 11	Smart Array 4250ES	Bus 15	Slot 11 also contains a bridged array controller, changing its original bus number from bus 14 to bus 15.

*Bus number is different than previous configuration.

Reviewing the Test 2 Configuration – Addition of Two Controllers

Configuration B–Test 2, illustrated in Table 8, provides an example of how the PCI BIOS discovers new controller devices not present in the original Test 1 configuration and how it assigns bus numbers during the discovery process. As in Test 1, the PCI BIOS moves through the bus detection order looking for controller devices (not slot numbers). In this example, the PCI BIOS begins at the Host Bus and assigns bus 0 to the Primary Bus. The PCI BIOS continues to search for the next device downstream on the Primary Bus. One bridged controller was added to the configuration on the Primary Bus. Upon discovery of each controller, the PCI BIOS assigns a bus number to the PCI bus on the bridged controller. Slot 2 now contains a NC3131 Fast Ethernet NIC on bus 1. Since slot 2 contained the last PCI device on the Primary Bus, the discovery process continues to the Secondary Bus.

The Secondary Bus is assigned a bus number of 6. The NC3131 Fast Ethernet NIC in slot 5, a bridged device, is discovered next. The PCI BIOS assigns bus 7 to the PCI bus on the controller, the last PCI controller discovered on the Secondary Bus.

The Tertiary Bus is assigned bus 13. The controllers downstream on the Tertiary Bus in slots 10 and 11 both contain bridges. Bus number assignments are made to the PCI buses on these bridged controllers. The Smart Array 4250ES Controller in slot 10 is assigned bus 14 and the Smart Array 4250ES Controller in slot 11 incremented to bus 15. Empty slots are ignored, because they do not contain PCI devices.

Comparison of Test 1 to Test 2 - Configuration B

When you reboot the server and run the System Configuration utility to view the hardware configuration changes, it displays slot and bus number assignments. Test 2 data was recorded and compared to Test 1.

A side-by-side comparison of the slot configurations and bus numbers of each device in Test 1 to the slot configurations and bus numbers of each device in Test 2, illustrates what bus numbers were changed after modifications took place.

Slot	Controller	Test 1	Test 2	Bus Assignment
Slot 1	Empty			N/A
Slot 2	NC3131 (bridged)		✓	Bus 1 - New
Slot 3	Empty			N/A
Slot 4	Empty			N/A
Slot 5	NC3131 (bridged)	✓	✓	Bus 7 – No Change
Slot 9	Empty			N/A
Slot 7	Empty			N/A
Slot 9	Empty			N/A
Slot 9	Empty			N/A
Slot 10	Smart Array 4250ES (bridged)		✓	Bus 14 – New
Slot 10	Smart Array 4250ES (bridged)	✓	✓	Bus 14 to 15 – Changed

Configuration C, ProLiant DL580

An example of a ProLiant DL580 server set up as an original Window NT server configuration. All the controllers included in this configuration were installed in the server before Windows NT

was loaded on the system. Windows NT detected network controllers in the original configuration during the installation process. However, when the configuration is modified in Test 2 PCI bus renumbering does occur.

Configuration C: Test 1 – Initial Configuration

Table 9. PCI BIOS bus detection in a ProLiant DL580–before removing and inserting NICs

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 1	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (0)**	Host to PCI Bridge	**Bus 0**	The PCI BIOS assigns 0 to the Primary Bus and continues downstream with the controller discovery.
2nd	Slot 5	Empty	N/A	Slot 5 is empty, no PCI bus number assignment.
3rd	Slot 6	Empty	N/A	Slot 6 is also empty, so PCI bus number assignment occurs.
4th	**Secondary Bus (4)**	Host to PCI Bridge	**Bus 4**	The PCI BIOS discovers the Secondary Bus and assigns it bus number 4.
5th	Slot 1	Smart Array 4200	Bus 5	Array controller in slot 1 contains a PCI bridge and the PCI BIOS increments the PCI bus number to 5.
6th	Slot 2	NC3131 (bridged)	Bus 6	Slot 2 contains a bridged NIC and assumes a bus number of 6.
7th	Slot 3	NC3132 (non-bridged)	Bus 4	Slot 3 contains a non-bridged NIC, which maintains the bus number on which it resides.
8th	Slot 4	NC3131 (bridged)	Bus 7	NIC in slot 4 contains a PCI bridge and the bus number increments to 7.

Reviewing the Test 1 Configuration

Configuration C–Test 1, illustrated in Table 9, provides an example of how the PCI BIOS discovers controller devices and assigns bus numbers during the discovery process. As the PCI BIOS moves through the bus detection order it looks for controller devices (not the slot numbers). In this example, the PCI BIOS begins at the Host Bus and moves downstream assigning bus numbers starting at bus 0 on the Primary Bus. In this scenario, no PCI devices reside on the Primary bus, so the discovery process continues to the Secondary Bus and assigns 4 as the bus number. The Smart Array 4200 Controller is the first device detected. Since this controller contains a PCI bridge the bus number increments to 5. Slot 2 contains a NC3131 Fast Ethernet NIC, which also contains a PCI bridge, incrementing the bus number once again. The NC3132 is discovered next, and since this device does not contain a PCI bridge, the bus number is assumes the bus number of the Secondary Bus (4). The final PCI controller discovered on the Secondary Bus, the NC3131 Fast Ethernet NIC (a bridged device), receives a bus number of 7.

IMPORTANT: The controllers added to the server configuration in our tests were selected only to illustrate how bus renumbering occurs. This is not meant to be a recommended configuration.

Configuration A – Test 2 – Removing and Adding NICs

The example in Table 10 illustrates the PCI BIOS discovery and bus number assignment process in the same ProLiant DL580 server, resulting in the reordering of bus numbers from the original configuration. When adding new network interface controllers (NIC) to a server, the slot used to input the device is significant since network connectivity can be lost for existing NICs in lower numbered slots. Fortunately, this state is only temporary because the NIC driver must be reconfigured to accommodate the new NIC, at which time the bindings for the other NICs will be rebuilt.

Table 10. PCI BIOS bus detection in a ProLiant DL580–after removing and adding NICs

Bus Detection Order/Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 2	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (0)**	Host to PCI Bridge	**Bus 0**	The PCI BIOS assigns 0 to the Primary Bus and continues downstream with the controller discovery.
2nd	Slot 5	Empty	N/A	Slot 5 is empty, no PCI bus number assignment.
3rd	Slot 6	Empty	N/A	Slot 6 is also empty, so PCI bus number assignment occurs.
4th	**Secondary Bus (4)**	Host to PCI Bridge	**Bus 4**	The PCI BIOS discovers the Secondary Bus and assigns it bus number 4.
5th	Slot 1	Smart Array 4200	Bus 5	Array controller in slot 1 contains a PCI bridge and the PCI BIOS increments the PCI bus number to 5.
6th	Slot 2	NC3131 (bridged)	Bus 6	Slot 2 contains a bridged NIC and assumes a bus number of 6.
7th	Slot 3	NC3131 (bridged)	Bus 7	In slot 3, a non-bridged device is replaced by a bridged one, causing the bus numbers of remaining slots to be reordered.
8th	Slot 4	NC3131 (bridged)	Bus 8	NIC in slot 4 contains a PCI bridge and the bus number increments to 8.

*Bus number is different than previous configuration

Reviewing the Test 2 Configuration

Windows NT enumerates the NIC instances on the PCI bus from the highest numbered slot to the lowest numbered slot. The bindings for each instantiation of the NIC drivers are dependent upon the PCI bus number of each NIC. Installation of a NIC in a slot between two NICs previously installed and configured in Windows NT can result in the loss of the network bindings of NICs in the lower numbered slots. However, this loss of bindings will only be a problem until the NIC driver is installed and bound to the NIC ports, which is required any time a new NIC is installed in a system.

In this scenario, installing the NC3131Fast Ethernet NIC, which is a bridged device, in slot 3 caused the newly installed NIC to assume the driver instance and bindings of the NIC installed in slot 4. Now, the NICs in slots 2 and 3 are bound to one another, leaving the NIC in slot 4 unbound until it is manually reconfigured. Note that only NICs inserted between NICs affect network bindings. Inserting a Smart Array Controller between two NICs causes no adverse effect.

Comparison of Test 1 to Test 2 - Configuration C

When you reboot the server and run the System Configuration utility to view the hardware configuration changes, it displays slot and bus number assignments.

A side-by-side comparison of the slot configurations and bus numbers of each device in Test 1 to the slot configurations and bus numbers of each device in Test 2, illustrates what bus numbers were changed after modifications took place.

Slot	Type Controller	Test 1	Test 2	Bus Assignment
Slot 1	Smart Array 4200 (bridged)	✓	✓	Bus 5 – No Change
Slot 2	NC3131 (bridged)	✓	✓	Bus 6 – No Change
Slot 3	NC3131 (bridged)		✓	Bus 4 to 7 - Change
Slot 4	NC3131 (bridged)	✓	✓	Bus 7 to 8 - Change
Slot 5	Empty			N/A
Slot 6	Empty			N/A

Updating the Server After the Configuration Changes

The server configuration now includes three network controllers. The controllers in slot 2 (original in Test 1), slot 3 (replaced in Test 2), and slot 4 (original in Test 1) are network controllers. These controllers must be reconfigured when the operating system is brought back up or they will not function. As stated earlier in this document, Windows NT records PCI controllers and bus numbers in the registry, but it does not automatically update the registry when the system is physically modified. Due to the nature of the PCI bus enumeration algorithm, removing a bridged PCI device might cause the bus numbers of other PCI devices to change. This change in no way affects your data or your applications.

Windows NT handles disk controllers differently, it detects the additional Smart Array 4200 Controller (and the attached drives); however, the order in which each disk/partition is listed in Disk Administrator might change. In other words, drive C: is still drive C: and drive D: is still drive D:, but the list of items that might change are available for review in the Windows NT Disk Administrator.

Rules of Thumb Before Adding More Controllers to a Server

In Test 2 several controllers are added to the system to provide additional support in Configuration C. This test configuration illustrates how PCI bus numbers are reassigned based on the reordered controllers in the server. Keep in mind, the following certain rules of thumb:

- Single port devices are generally not bridged and assume the bus number of the bus on which they reside. However, the SMART-2/SL Drive Array Controller is an exception to the rule (see next bullet); it is a single-port intelligent bridged disk device.

- Multiple port (dual network NICs) and intelligent devices (SMART-2 Controllers and Smart Array Controllers) often contain bridges and receive a bus number assignment for each PCI bus.

During this process, complete the following:

- Do not place all network controllers on the same bus, and do not place all disk controllers on the same bus. Balance the load between buses for optimal performance.

- Record all important network settings and numbers before you make changes (protocols, frame types, IP addresses, etc).

- Run the Disk Administrator after Windows NT installation to ensure that the boot drive receives a signature properly (Drive C:). Use the Disk Administrator to label disk controllers in case the disks become renumbered in the new configuration. Systems with a large disk expansion base can be hard to sort out without labels.

- Determine what tools to use ahead of time for resetting the system should the need occur.

Reestablishing Network Connections

The following section describes how the various Compaq and Windows NT utilities can provide assistance in verifying connections and reestablishing network links. Again, this is not a complete list of tools, but the ones that our testing found the most helpful.

Compaq Network Teaming and Configuration Utility

The Compaq Network Teaming and Configuration Utility is the Microsoft Windows NT 4.0 application for configuring Compaq 10/100 and Gigabit NICs.

Note: If your server contains a TLAN-based network controller, you must use the Compaq TLAN Teaming and Configuration Utility referenced in Appendix C.

The applet for this utility can be found in the Windows NT Control Panel with an icon labeled Compaq Network. This utility installs from the Compaq Support Paq for Microsoft Windows NT 4.0, if the system contains Compaq network controllers based on Intel technology.

This utility supports the following controllers:

- Compaq NC1120 Ethernet NIC

- Compaq NC3120 Fast Ethernet NIC (PCI 10/100)

- Compaq NC3121 Fast Ethernet NIC (PCI 10/100 WOL)

- Compaq NC3122 Fast Ethernet NIC (PCI Dual 10/100) (82558)

- Compaq NC3123 Fast Ethernet NIC (82559)

- Compaq NC3131 Fast Ethernet NIC (Dual Base 10/100) (82558)

- Compaq NC3132 Fast Ethernet Upgrade Module (Dual 10/100) for NC3131 and NC3134 Server NICs (82558)

- Compaq NC3133 100FX Upgrade Module for NC3131 and NC3134 Server NICs

- Compaq NC3134 Fast Ethernet Server NIC (82559)

- Compaq NC3135 Fast Ethernet Upgrade Module for NC3131 and NC3134 Server NICs (82559)

- Compaq NC3160 Upgrade Module for NC3131 and NC3134 Server NICs (82559)

- Compaq NC3160 Fast Ethernet NIC

- Compaq NC3161 Fast Ethernet NIC

- Compaq NC6132 1000 SX Gigabit Upgrade Module for NC3131 and NC3134 Server NICs

- Compaq NC6133 1000 LX Gigabit Upgrade Module for NC3131 and NC3134 Server NICs

- Compaq NC6134 Gigabit NIC (PCI 1000 SX)

The procedures that follow describe how to install and uninstall network controllers using the Compaq Network Teaming and Configuration Utility. The features discussed here do not describe all the capabilities of this utility. The configuration in Configuration C–Test 2 must be reconfigured in Windows NT after several new controllers are added to the ProLiant DL580 server. The following section illustrates how to reconfigure a controller(s).

Main Window:

Each Compaq Ethernet, Fast Ethernet, or Gigabit network controller that you install as standalone must have a separate driver instance in Microsoft Windows NT. If any unbound services exist, the Compaq Network Teaming and Configuration Utility detects them when the utility starts and displays the status of each. Here are some reasons why you would see these results:

- You physically removed a controller and did not uninstall it first.

- You physically moved an installed controller to another slot without uninstalling it first.

- You physically removed or added a bridged PCI controller.

The following procedures describe how to configure bindings that became unbound due to one of the above mentioned reasons.

After the network controllers were modified in Configuration C and the Compaq Network Teaming and Configuration Utility is accessed:

1. Select **Start → Settings → Control Panel**.

2. Select the **Compaq Network** icon to launch the Compaq Network Teaming and Configuration Utility. Figure 10 shows the controllers requiring reconfiguration in Configuration C.
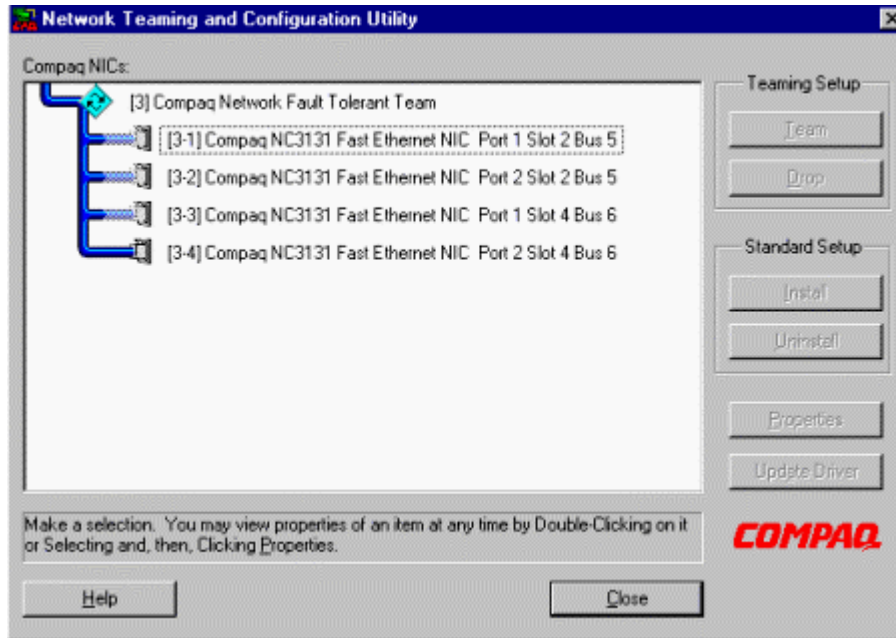
Figure 10. NICs in configuration c – test 2 before being reconfigured

Uninstalling and/or Installing a Standalone Controller

Here are the steps to follow to install and uninstall controllers. To install network controllers that are configured as standalone, follow these steps:

Uninstalling a Controller:

1. Double click **Start → Settings → Control Panel**.

2. Select the Compaq Network icon to launch the Network Teaming and Configuration Utility.
   a. Highlight the controller that did not load (no other controllers should be selected).
   b. Click the **Uninstall** option.

3. Select the **Close** button when finished.

   This will immediately uninstall the controller (i.e., remove its entries from the registry). The driver for this adapter will not be removed from memory until the system is restarted.

Installing a Controller:

1. Double-click **Start → Settings → Control Panel**.
   a. Highlight the uninstalled controller you want to install (no other controllers should be selected).
   b. Select the **Install** option.

2. Select the **Close** button when finished.

Once the installation completes, the controller turns yellow. This indicates that the registry contains the controller, but the driver is not currently loaded in memory (the driver loads the next time the system restarts). All installed controllers have a number in brackets next to their name. This is the network card number for that driver instance. You must restart the server for the changes to take effect.

After the computer restarts, Figure 7 shows that the computer, the slot, and the bus number information agree with the Configuration C results:

- Slot 2 contains a NC3131 Fast Ethernet NIC on Bus 5.

- Slot 3 contains a NC3131 Fast Ethernet NIC on Bus 6.

- Slot 4 contains a NC3131 Fast Ethernet NIC on Bus 7.
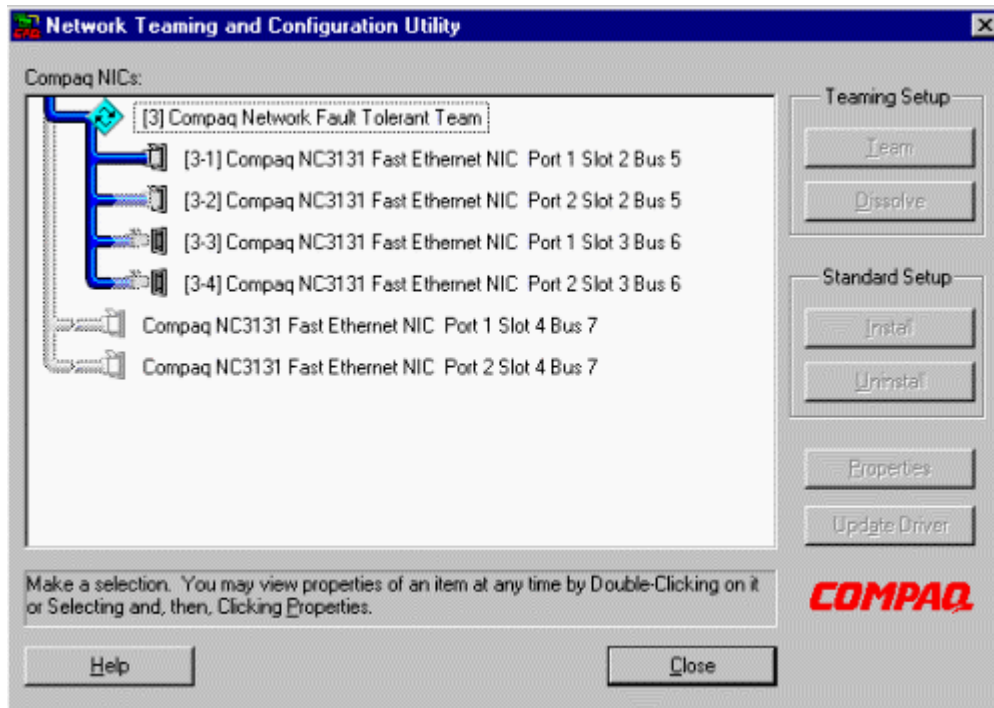
Figure 11.   NICs in configuration c–test 2 after being reconfigured

Configuring Other Manufacturer's Network Controllers with the Network Applet

If your server includes other manufacturer's network controllers, perform the following steps to reset the controller:

1. Double-click on the Network icon, in the Windows NT Control Panel, and record pertinent information on all controllers in the server.

2. Highlight the controller that did not load and select the **Remove** option.

   Note: The Remove and Add steps are a manual process and must be performed separately.

3. Re-add the controller by selecting the controller from the Adapter List and then select **Continue**.

4. Enter the controller information recorded (IP address, etc.) in the Network Settings dialog box.

5. Shut down and restart the server when the network controller configuration completes.

When configuration changes are made affecting other manufacturer's controllers, the Compaq Network Teaming and configuration Utility to reestablish bindings (required when the controller receives a new bus number because of modifications).

Compaq Support Software and Utilities

This section provides a brief review of several of the Compaq support software utilities used as test and configuration tools to develop this white paper.

Compaq Systems Configuration Utility

The Compaq Systems Configuration Utility, a tool used to configure Compaq servers, runs each time you change the physical hardware of an optional component in the server. It displays the physical slot number for each installed controller board and, in most cases, the bus number. You can find it on the Compaq SmartStart and Support Software CD and on the Compaq website at http://www.compaq.com/support/files/server/us/index.html.

Compaq Support Paq (CSP) for Microsoft Windows NT 4.0

The Compaq Support Paq (CSP) for Microsoft Windows NT 4.0 provides driver and software utilities to support value-added features on Compaq servers. Several of the utilities and drivers discussed in this document include features that support PCI bus numbering. Discussion relative to the Compaq Support Paq feature set is limited to the scope of this document. This software is available on the Compaq SmartStart and Support Software CD and on the Compaq website at http://www.compaq.com/support/files/server/us/index.html.

Compaq PCI Hot Plug Utility

The PCI Hot Plug Utility provides a common point for managing the PCI Hot Plug buses on the local system, as well as remote systems accessible over the network. Compaq PCI Hot Plug software for Windows NT includes hot-plug aware device drivers, operating system support, and the PCI Hot Plug Utility. The PCI Hot Plug Utility graphically provides a method of identifying slot and controller installation and bus number assignment. Hot plug aware device drivers enable the system to halt operations on a specific controller prior to removing the controller.

The Compaq PCI Hot Plug Utility is part of the Compaq Support Paq, which can be obtained from the Compaq SmartStart and Support Software CD and on the Compaq website at http://www.compaq.com/support/files/server/us/index.html. Once installed, the utility appears as the Compaq PCI Hot Plug applet under Control Panel, as well as appearing in the screen, as shown in a special Compaq System Tools folder. A complete description of all the capabilities and features of this utility are documented in the Deploying PCI Hot Plug on Compaq Servers in a Microsoft Windows NT Environment, July 1997 - Doc ID 064A/0797 white paper.

Compaq Array Configuration Utility

The Array Configuration Utility configures SMART-2 Array and Smart Array controllers. It also provides a view of the disk numbers that Windows NT assigns to drive arrays and disk volumes. Once installed, the utility appears under Programs in the Compaq System Tools folder. This utility is available from within the system boot partition as a selection in the Systems Configuration utilities. It is also an installation option as a GUI tool with the Compaq Support Paq when drive arrays are detected on the server.

The Compaq Array Configuration Utility is packaged as a Smart Component and as part of the Compaq Support Paq, which may be found at the following locations:

- Compaq SmartStart and Support Software CD

- Compaq website at http://www.compaq.com/support/files/server/us/index.html

Compaq Network Teaming and Configuration Utility

This network-monitoring tool allows you to install, uninstall, configure and monitor Compaq 10/100 and Gigabit adapters. This utility also displays and provides a method of updating PCI bus number assignments, bus type, and slot numbers associated with each device. A complete description of all the capabilities and features of this utility are documented in the utility Help file. This utility is packaged in the Smart Component called Compaq Ethernet/Fast Ethernet or Gigabit NIC Driver for Windows NT 4.0, available as an individual component and within the Compaq Support Paq for Microsoft Windows NT 4.0, on the Compaq SmartStart and Support Software CD and on the Compaq Website at http://www.compaq.com/support/files/server/us/index.html.

For retired Compaq servers, refer to the "Compaq TLAN Teaming and Configuration Utility" section in Appendix C.

Compaq Survey Utility for Windows

This utility contains an online agent that captures critical hardware and operating system configuration information on Compaq servers without interrupting server operation. It automates a configuration history log, allowing administrators to identify and compare configuration changes. This utility also details PCI device number and slot number assignments.

This utility provides a survey of the system on a periodic basis and provides printable history file called survey.txt. You can use it to identify changes to the system. Refer to the Readme.txt file for detail information about using this utility.

The information the Survey Utility gathers is accessible locally at the host server console. From the console you can view the Survey Utility file online, get an updated snapshot of a server's configuration, and generate new output files. The Survey Utility outputs the information it gathers into SURVEY.TXT. This file is located in [Windows NT Drive]:\COMPAQ\SURVEY for Windows NT. The Survey Utility is normally installed to run at startup and at specified time intervals. This helps to ensure that the latest information and change history is always recorded and available when needed. You can modify the data-gathering interval by modifying the command line parameters. The Compaq Survey Utility allows you to resolve problems without taking the server offline and to assist in maximizing server availability. This utility downloads as an individual Smart Component or as part of the Compaq Support Paq for Microsoft Windows NT 4.0 via the Compaq website at http://www.compaq.com/support/files/server/us/index.html. It can also be installed from the Compaq Integration Maintenance Utility, if you set up your server with the Compaq SmartStart and Support Software CD and the Compaq Management CD.

Windows NT Disk Administrator

Disk Administrator, a graphical tool for managing disks, provides status information about disks, such as the partition sizes and the amount of free space available for creating additional partitions. It also includes status information, such as the disk number assignment, drive-letter assignment, volume label, file system type, and size.

The illustration in Figure 12 illustrates how labels can assist you to identify drives and volumes in the server. Without labels, the disk can only be identified by the drive letter.

IMPORTANT: Compaq strongly recommends that you label disks and volumes with meaningful labels.

Sometimes due to configuration changes, Windows NT reorders the disk drives. Drives and volumes that contain descriptive labels can more readily be identified when the system is brought back on line. This might not be a problem in small server configurations; however, as a network grows with more drives and volumes added, drive identification could become difficult, if not impossible, to monitor.
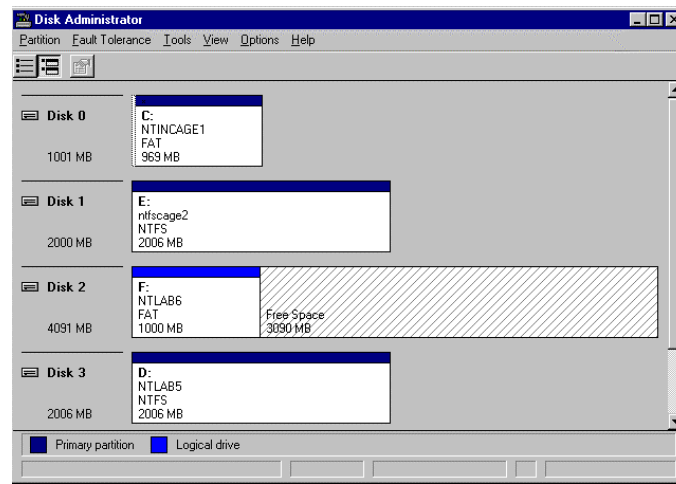

Figure 12. Including disk labeling in a server configuration

Additional Troubleshooting Tips

Table 11 lists the PCI bus detection order, Primary and Secondary bus locations, and slot numbers for the several ProLiant servers. This matrix can help you identify how the PCI BIOS assigns bus numbers in these servers. The ProLiant 8000 includes triple-peer PCI Bus architecture, the ProLiant ML530 and ProLiant DL380 contain highly parallel PCI Bus architecture, and all of the others are dual-peer PCI Bus architecture servers. This matrix illustrates the differences in the PCI bus number detection order from one server model to another.

Table 11. PCI Bus Number Order of Detection Matrix

Bus	Triple-Peer PCI Buses	Highly Parallel PCI Buses		Dual-Peer PCI Buses	
Detect/ Order Controller Discovery	ProLiant 8000	ProLiant DL380	ProLiant ML530	ProLiant ML350	ProLiant DL580
1st	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge
2nd	Slot 1 - Pri Bus	Slot 1 - Pri Bus	Slot 1 - Pri Bus	Slot 1 - Pri Bus	Slot 5 – Pri Bus
3rd	Slot 2 - Pri Bus	Secondary Host to PCI Bridge	Secondary Host to PCI Bridge	Slot 4 - Pri Bus	Slot 6 – Pri Bus
4th	Slot 3 - Pri Bus	Slot 2 - Sec Bus	Slot 7 - Sec Bus	Slot 5 - Pri Bus	Secondary Host to PCI Bridge
5th	Slot 4 - Pri Bus	Slot 3 - Sec Bus	Slot 8 - Sec Bus	Slot 6 - Pri Bus	Slot 1 - Sec Bus
6th	Secondary Host to PCI Bridge	Slot 4 - Sec Bus	Tertiary Host to PCI Bridge	Secondary Host to PCI Bridge	Slot 2 - Sec Bus
7th	Slot 5 – Sec Bus		Slot 6 - Ter Bus	Slot 2 - Sec Bus	Slot 3 - Sec Bus
8th	Slot 6 – Sec Bus		Slot 4 - Ter Bus	Slot 3 - Sec Bus	Slot 4 - Sec Bus
9th	Slot 7 – Sec Bus		Slot 3 - Ter Bus		
10th	Slot 8 - Sec Bus		Slot 2 – Ter Bus		
11th	Slot 9 - Sec Bus		Slot 5 – Ter Bus		
12th	Tertiary Host to PCI Bridge				
13th	Slot 10 – Ter Bus				
14th	Slot 11 – Ter Bus				

Primary Bus = Pri Bus; Secondary Bus = Sec Bus; Tertiary Bus = Ter Bus

In addition to this matrix, there is a PCI Bus Numbering HTML calculation tool for each server in Table 11. You can access these tools on the Internet by going to the Compaq and Microsoft

Frontline Partnership site
http://www.compaq.com/partners/microsoft/resourcepaq/utilities/pci.html. You can use these tools to enter Compaq PCI bridged and non-bridge controllers in PCI slots for any of the servers included in Table 11. The bus numbers are immediately displayed when you select a controller and place it in a slot.

Additional tips to remember:

- Install PCI video controllers on the Primary Bus. Some video controllers require allocation of memory below the 1-megabyte boundary. The Intel 82450GX chip set architecture dictates that this memory is only available to devices on the Primary PCI bus. Video controllers installed on the Secondary PCI bus will probably not work.

- Ensure that you are adding PCI devices to the appropriate PCI bus. Some older third-party controllers might not operate properly on the secondary bus due to driver incompatibilities. You might receive a message similar to "Device not Found." To correct this problem, install the controller in the Primary Bus. Also, contact the device vendor to determine if an upgraded driver will correct this problem.

Summary

PCI Bus numbers are determined during each and every boot cycle. Systems Administrators understanding the PCI BIOS bus numbering and discovery process eliminate unnecessary system downtime. As discussed in this white paper, adding and removing PCI devices might cause a renumbering of PCI buses. Windows NT does not automatically detect that bus were renumbered the server is booted. However, configuration mismatches are correctable using the tools that Compaq and Microsoft provide with Windows NT and several Compaq support software tools.

This document provides the information needed to determine PCI bus numbers and plan how any potential bus numbering changes will affect the system.

Appendix A, Slot Design for Retired Compaq ProLiant Servers

Retired Compaq ProLiant Servers

The PCI bus numbering scheme of four retired Compaq ProLiant server models are detailed in this appendix.
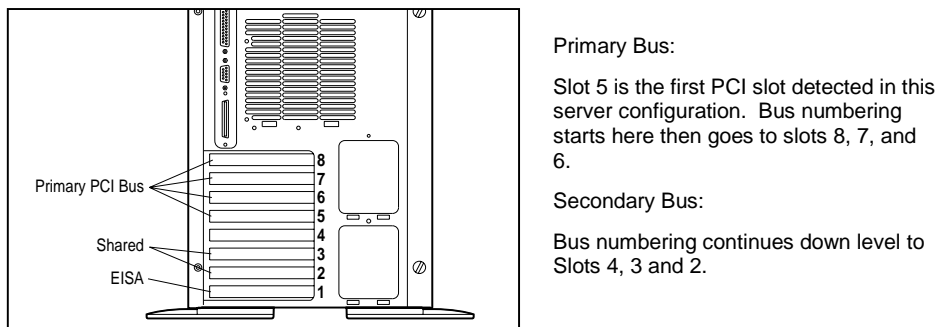
Note: The features discussed in this section are not to be considered a complete description for any of the server or option hardware. Refer to the specification for each product to learn more about the complete feature set. This information is available on the Compaq Web at http://www.compaq.com/products/servers.

The ProLiant 6500 PCI bus numbering results are described in Configuration A. Discussion of the ProLiant 5000 server is limited to the differences in the bus and slot design from the ProLiant 6000, ProLiant 6500, and ProLiant 7000 servers and how the bus numbering scheme is affected.

The ProLiant 6000 and ProLiant 7000 servers PCI bus numbering results are described in Configuration B. The ProLiant 6000 and ProLiant 7000 servers share certain similarities in their architecture and features. For this reason, these two servers were tested in the same scenario and compared. Each server contains the dual-peer PCI buses architecture and the same Intel Pentium Pro chip set.

ProLiant 5000

The ProLiant 5000 has a total of 8 slots: 5 PCI slots, 2 shared compatibility PCI/EISA slots; and 1 EISA slot.

Primary Bus:

Slot 5 is the first PCI slot detected in this server configuration. Bus numbering starts here then goes to slots 8, 7, and 6.

Secondary Bus:

Bus numbering continues down level to Slots 4, 3 and 2.

Figure 13. Internal slot view of the ProLiant 5000

ProLiant 6500

ProLiant 6500 is a dual-peer bus and has 8 PCI slots: 2 shared compatibility PCI/EISA slots and 6 hot plug secondary PCI slots.
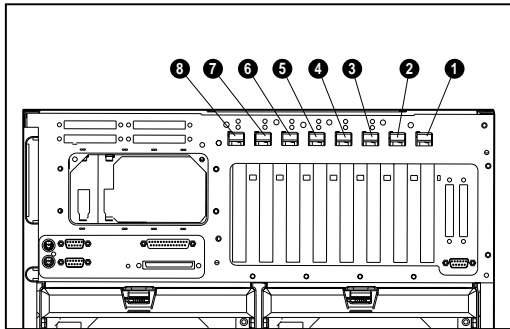
Primary Bus:

Slots 1 and 2 are shared PCI/EISA slots in this server configuration. Bus numbering starts here and works it way down to the Secondary Bus.

Secondary Bus:

Bus numbering continues down to the hot pluggable slots 3 - 8.

Figure 14. Internal slot view of the ProLiant 6500

Design Comparisons ProLiant 6000 and ProLiant 7000 (Pentium Pro processor):

As stated earlier, the ProLiant 6000 and ProLiant 7000 servers have similar architectural design. Both servers are dual-peer PCI buses that consist of 6 slots on the Primary Bus (4 are PCI starting at slot 3, slots 1 and 2 are EISA). The Secondary Bus contains five PCI slots, numbered 7-11. The PCI bus number detection process begins with slot 3 on the Primary Bus. The results of tests performed on these two servers are combined for the purpose of showing results. The most obvious difference between these two servers is that the ProLiant 7000 supports hot plug slots in the Secondary Bus (slots 7-11).

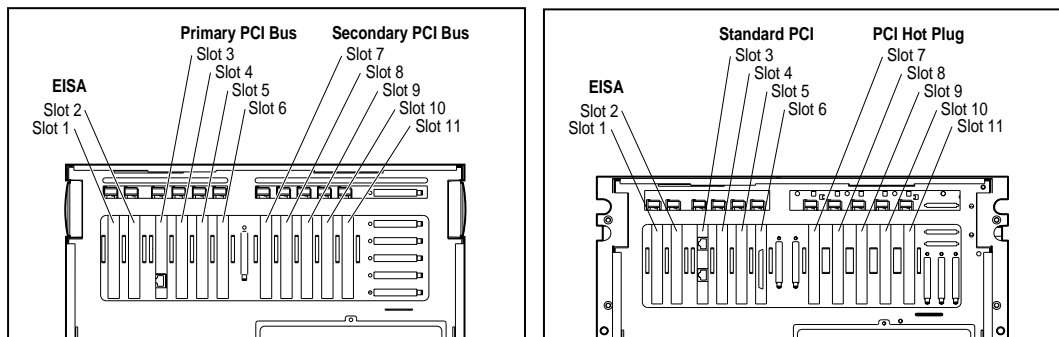A slot comparison diagram of each server follows:

Figure 15. Location of expansion slots in rear of the ProLiant 6000 and 7000

Appendix B, PCI Test Configurations with Retired ProLiant Servers

The following scenarios were tested in the Compaq Integration Lab. The scenarios demonstrate how the PCI BIOS assigns the bus numbers and then reassigns the bus numbers based on configuration modifications. The following examples demonstrate the step-by-step changes that occur:

- Configuration A: Test 1 – Initial Configuration and Test 2 – Adding a Device.

- Configuration B: Test 1 – Initial Configuration and Test 2 – Addition of Two Controllers.

By understanding what configuration changes occur in the test scenarios described in this section, you can better understand how PCI Bus numbers are reassigned when configuration changes occur in your server. "Table 17. PCI Bus Number Order of Detection Matrix", included in Appendix D, identifies the Controller Discovery Order for each of these servers and several others.

Configuration A, ProLiant 6500 server (dual-peer architecture), a two configuration scenario: The PCI slot layout is different than the ProLiant 5000, ProLiant 6000 and ProLiant 7000 servers. This scenario walks through a simple Windows NT configuration and shows how the bus numbers change when you add a new controller to the server. The configurations are illustrated in two tables with a side bar description of what the PCI BIOS does during the discovery process.

Configuration B, ProLiant 6000 and 7000 servers (dual-peer architecture), a more complex two configuration scenario tested on both the ProLiant 6000 and ProLiant 7000 servers: The results were identical for both these servers. The servers were modified to include additional disk and network controllers. The configurations are illustrated in two tables with a side bar description of what the PCI BIOS does during the discovery process.

The ProLiant 5000 server was tested with similar configuration scenarios, but the results are not included in this white paper. The most notable difference about this server is the PCI slot layout and PCI bus number detection order is different from each of the above mentioned servers. The PCI slots in the ProLiant 5000 are identified in a different device number-ordering scheme. The first slot to be discovered on the Primary Bus by the PCI BIOS is slot 5 bus 0, followed by slots 8, 7, 6, 4, 3 and finally 2. The test results for bus numbering assignments occurred in the same manner as it did in the other servers tested.

IMPORTANT: Be aware that the bus number detection process in the ProLiant 5000 server is not in sequential slot number order. Keeping that in mind, all other numbering considerations follow the results described in Configuration A.

Configuration A, ProLiant 6500

All the controllers included in this configuration were installed in the server before Windows NT was loaded on the system. Windows NT detected network controllers in the original configuration during the installation process. However, when the configuration is modified in Test 2 PCI bus renumbering does occur.

Configuration A: Test 1 – Initial Configuration

Even though PCI bus numbers are assigned during every boot process, the assignment is exactly the same as long as the configuration remains the same.

This bus number and controller discovery test was performed on a simple configuration in a dual-peer PCI ProLiant 6500 server. This configuration is described as simple because it contains only two non-bridged PCI network controllers.

Table 12. PCI BIOS bus detection in a ProLiant 6500 – before adding a bridged controller

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type – Test 1	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (0)**	Host to PCI Bus Bridge	**Bus 0**	The PCI BIOS discovers the Primary Bus and assigns it bus 0.
2nd	Slot 1	Netelligent 10/100 TX	**Bus 0**	PCI BIOS detects a NIC (no PCI bridge) in slot 1, it is assigned the same bus number as the PCI Bus where it resides, and is the first controller detected by the PCI BIOS.
3rd	Slot 2	Empty	N/A	Discovery process continues to PCI slot 2. No PCI controller detected, no bus number assigned.
4th	**Seconda ry Bus (1)**	Host to PCI Bus Bridge	**Bus 1**	The PCI BIOS discovers the Secondary Bus and increments the bus number to 1.
5th	Slot 3	Empty	N/A	Discovery process continues to PCI slot 3. No PCI controller detected no bus number assigned.
6th	Slot 4	Netelligent 10/100 TX	**Bus 1**	PCI BIOS detects a NIC (no PCI bridge) in slot 4 it is assigned the same bus number as the PCI Bus where it resides, bus 1.
7th	Slot 5	Empty	N/A	Discovery process continues to PCI slot 5. No PCI controller detected, no bus number assigned.
8th	Slot 6	Empty	N/A	Discovery process continues to PCI slot 6. No PCI controller detected, no bus number assigned.
9th	Slot 7	Empty	N/A	Discovery process continues to PCI slot 7. No PCI controller detected, no bus number assigned.
10th	Slot 8	Empty	N/A	Discovery process continues to PCI slot 8. No PCI controller detected, no bus number assigned.

Reviewing the Test 1 Configuration

In Test 1, the PCI BIOS begins the discovery process by identifying buses on the Primary PCI Bus. It continues to the Secondary PCI Bus looking for PCI buses and or bridges. As each bus is detected it is assigned a bus number starting at bus 0, the PCI BIOS then assigns bus numbers to

the PCI controllers discovered on each bus. In this example, the controllers do not contain bridges. Therefore, they are assigned the same bus number as the bus on which they reside.

Configuration A – Test 2 – Adding a Device

The next example in Table 13 illustrates the PCI BIOS discovery and bus number assignment process in the same dual-peer PCI ProLiant 6500 server. However, the configuration changes slightly by adding a bridged PCI disk controller on the Primary Bus.

Table 13. PCI BIOS bus detection in a ProLiant 6500 – after adding a bridged controller

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 2	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (0)**	Host to PCI Bus Bridge	**Bus 0**	The PCI BIOS discovers the Primary Bus and assigns it bus 0. PCI BIOS detects a NIC (no PCI bridge) in slot 1, it is assigned the same bus number as the PCI Bus where it resides, and is the first controller detected by the PCI BIOS.
2nd	Slot 1	Netelligent 10/100 TX	**Bus 0**	
3rd	Slot 2	(new device) SMART-2/P Drive Array	**Bus 1***	Discovery process continues to PCI slot 2. PCI BIOS detects a SMART-2 disk controller (PCI bridge device) in slot 2, it detects the PCI bridge on the controller and increments the bus number to 1.
4th	**Secondary Bus (1)**	Host to PCI Bus Bridge	**Bus 2***	The PCI BIOS discovers the Secondary Bus and increments the bus number to 2. Changing the bus number assignment from the original configuration.
5th	Slot 3	Empty	N/A	Discovery process continues to PCI slot 3. No PCI controller detected, no bus number assigned.
6th	Slot 4	Netelligent 10/100 TX	**Bus 2***	PCI BIOS detects a NIC (no PCI bridge) in slot 4, it takes the same bus number assignment as the Secondary PCI Bus where it resides, bus 2. Changing the bus number assignment from the original configuration.
7th	Slot 5	Empty	N/A	Discovery process continues to PCI slot 5. No PCI controller detected, no bus number assigned.
8th	Slot 6	Empty	N/A	Discovery process continues to PCI slot 6. No PCI controller detected, no bus number assigned.
9th	Slot 7	Empty	N/A	Discovery process continues to PCI slot 7. No PCI controller detected, no bus number assigned.
10th	Slot 8	Empty	N/A	Discovery process continues to PCI slot 8. No PCI controller detected, no bus number assigned.

*Bus number is different than previous configuration

Reviewing the Test 2 Configuration

In Test 2, as in Test 1, the PCI BIOS begins the discovery process by identifying buses on the Primary PCI Bus which is assigned bus 0. The network controller in slot 1 is also assigned bus 0 as it was before. Slot 2 on the Primary Bus now contains a SMART-2/P Drive Array (a bridged controller), which increments the bus number assignment to bus 1. This changes all bus number assignments detected after this controller in the discovery order. The Secondary PCI Bus previously assigned bus 1 is now incremented to bus 2. Slot 4 still contains the non-bridged network controller and it receives the bus number of the bus where it resides, in this example bus 2.

At this point, Windows NT is not aware that the bus number assignments have changed. The bindings for the network controller in slot 4 are no longer applicable and must be manually reset for this controller to function in the configuration once again. Refer to the "Compaq TLAN Network Teaming and Configuration" section in this document for instructions on how to reset the bindings.

Comparison of Test 1 to Test 2 - Configuration A

When you reboot the server and run the System Configuration utility to view the hardware configuration changes, it displays slot and bus number assignments. Test 2 data was recorded and compared to Test 1.

A side-by-side comparison of the slot configurations and bus numbers of each device in Test 1 to the slot configurations and bus numbers of each device in Test 2, illustrates what bus numbers were changed after modifications took place.

Slot	Type Controller	Test 1	Test 2	Bus Assignment
Slot 1	Netelligent 10/100 TX (non-bridged)	✓	✓	Bus 0 - No Change
Slot 2	SMART-2/P Drive Array (bridged)		✓	Bus 1 – New
Slot 3	Empty			N/A
Slot 4	Netelligent 10/100 TX (non-bridged)	✓	✓	Bus 1 to Bus 2 - Changed
Slot 5	Empty			N/A
Slot 6	Empty			N/A
Slot 7	Empty			N/A
Slot 8	Empty			N/A

Configuration B, ProLiant 6000 and 7000

Test 1 is the first of two installations tested on the ProLiant 6000 and ProLiant 7000 servers. Each server was set up as an original Window NT server configuration. All the controllers included in this configuration were installed in the server before Windows NT was loaded on the system. Because they were a part of the original configuration, Windows NT detected the network controllers during the installation process. However, when additional controllers are later added to the system in a modified configuration, PCI bus renumbering does occur. The information that follows in this section explains these changes as they occur and how you can easily modify Windows NT with several Compaq and Windows NT utilities.

The diagrams in Figure 16 illustrate the location of the expansion slots in the rear of the ProLiant 6000 and 7000 servers. Both servers share the same bus design and slot layout; however, the ProLiant 7000 server contains hot pluggable slots on the Secondary Bus as shown in Figure 16.
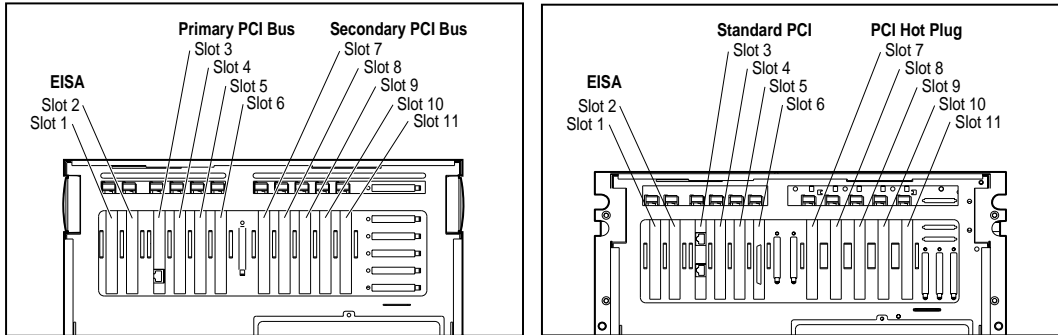
Figure 16. Location of expansion slots in rear of the ProLiant 6000 and 7000 servers

Bus number assignments for controllers with bridged devices are assigned to the device on the controller.

Table 14 illustrates the relationship between slot numbers, controller installation, and PCI BIOS bus assignments in Configuration B–Test 1. This test includes several bridged controllers to demonstrate bus renumbering in a more complex configuration.

Table 14. Test 1 – PCI BIOS bus detection in the ProLiant 6000 and 7000 servers

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 1	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (0)**	Host to PCI Bus Bridge	**Bus 0**	The PCI BIOS assigns 0 to the Primary Bus and continues downstream with the controller discovery.
2nd	Slot 1 (EISA)	N/A	N/A	
3rd	Slot 2 (EISA)	N/A	N/A	The NIC in slot 3 does not contain a PCI bridge device, it assumes the bus number of the bus where it resides, which in this case is bus 0. It is the first network controller detected by the PCI BIOS.
4th	Slot 3	Netelligent 10/100 TX	**Bus 0**	
5th	Slot 4	Empty	N/A	Intelligent drive array controller with PCI bridge is detected in slot 6. The PCI BIOS increments the PCI number to bus 1 and assigns it to the bridge on the controller.
6th	Slot 5	Empty	N/A	
7th	Slot 6	SMART-2/SL Drive Array	**Bus 1**	The PCI BIOS discovers the Secondary Bus and assigns it bus number 2.
8th	**Secondary Bus (2)**	Host to PCI Bus bridge	**Bus 2**	Intelligent drive array controller (a PCI bridge device) detected in slot 8. The PCI BIOS increments the PCI bus number to 3 and assigns the bus number to the bridge on the controller.
9th	Slot 7	Empty	N/A	
10th	Slot 8	SMART-2/SL Drive Array	**Bus 3**	
11th	Slot 9	Empty	N/A	NIC in slot 10 contains a PCI bridge and the PCI BIOS increments the PCI bus number to 4.
12th	Slot 10	Netelligent Dual 10/100 TX	**Bus 4**	Slot 11 is empty, no PCI bus number assignment.
13th	Slot 11	Empty	N/A	

Reviewing the Test 1 Configuration – Initial Configuration

Configuration B–Test 1, illustrated in Table 14, provides an example of how the PCI BIOS discovers controller devices and assigns bus numbers during the discovery process. As the PCI BIOS moves through the bus detection order it looks for controller devices (not the slot numbers). In this example, the PCI BIOS begins at the Host Bus and moves downstream assigning bus numbers starting at bus 0 on the Primary Bus. If the PCI BIOS detects a PCI device and it does not contain a bridge it receives the bus number assignment of the bus on which it resides. In this scenario, the Netelligent 10/100 TX Controller in slot 3 does not contain a bridge so it receives a bus assignment of bus 0. The PCI BIOS continues to search for the next device on the Primary Bus. The SMART-2/SL Drive Array Controller in slot 6, a bridged device, is discovered next. The PCI BIOS assigns bus 1 to the PCI bus on the bridged controller. This is the last PCI controller discovered on the Primary Bus.

At this point, the PCI BIOS discovery process continues to the Secondary Bus where it increments the bus assignment to 2. The controllers detected later in the discovery order on the Secondary Bus (slots 8 and 10) both contain PCI bridges. Bus number assignments are made to the PCI buses on these controllers. The SMART-2/SL Drive Array controller in slot 8 is assigned bus 3 and the Netelligent Dual 10/100 TX controller in slot 10 is assigned bus 4. Empty slots are ignored, because they do not contain PCI devices.

IMPORTANT: The controllers that Compaq added to the server configuration were selected only to illustrate how bus renumbering occurs. Several different SMART Array and network controllers were included to demonstrate that they all respond to renumbering in the same manner. This is not meant to be a recommended configuration.

Test 2 in Table 15 illustrates how bus assignments change when physical configuration changes occur in the server.

Table 15. Test 2 – PCI BIOS bus detection in the ProLiant 6000 and 7000 servers

Bus Detection Order/ Controller Discovery	Slot Number	PCI Bridge/ Controller Type - Test 2	Bus Number Assignment	Description of PCI BIOS Discovery Process
1st	**Primary Bus (0)**	**Host to PCI Bus bridge**	Bus 0	As with Test 1, the PCI BIOS assigns 0 to the Primary Bus and continues downstream with the controller discovery process.
2nd	Slot 1 (EISA)	N/A	**N/A**	
3rd	Slot 2 (EISA)	N/A	N/A	The NIC in slot 3 does not contain a PCI bridge it assumes the bus number of the bus where it resides, which in this case is bus 0. It is the first network controller detected by the PCI BIOS.
4th	Slot 3	Netelligent 10/100 TX	Bus 0	
5th	Slot 4	(new device) SMART-2/P Drive Array	**Bus 1***	A PCI bridged Intelligent drive array controller was ADDED to the server in slot 4. The PCI BIOS increments the PCI bus number to 1 and assigns it to the bridge on the controller.
6th	Slot 5	(new device) Netelligent Dual 10/100 TX	**Bus 2***	A PCI bridged NIC was ADDED to the server in slot 5. The PCI BIOS increments the PCI bus to 2 and assigns the bus number to the bridge on the controller. All bus numbers assigned later in the discovery from here are affected.
7th	Slot 6	SMART-2/SL Drive Array	**Bus 3***	Intelligent drive array controller with a PCI bridge detected in slot 6. The PCI BIOS increments the PCI number to bus 3 and changes the assignment of the bus number on the array controller.
8th	**Secondary Bus (4)**	Host to PCI Bus bridge	**Bus 4***	The PCI BIOS discovers the Secondary Bus and assigns it bus 4, a changed number.
9th	Slot 7	Empty	N/A	
10th	Slot 8	SMART-2/SL Drive Array	**Bus 5***	Intelligent drive array controller with PCI bridge detected in slot 8. The PCI BIOS increments the PCI bus number to 5 changing the bus number assignment on the array controller.
11th	Slot 9	Empty	N/A	Slot 9 is empty, no PCI bus number assignment
12th	Slot 10	Netelligent Dual 10/100 TX	**Bus 6***	NIC in slot 10 contains a PCI bridge and the PCI BIOS increments the bus number to 6 changing the bus number assignment.
13th	Slot 11	Empty	N/A	Slot 11 is empty, no PCI bus number assignment.

*Bus number is different than previous configuration.

Reviewing the Test 2 Configuration – Addition of Two Controllers

Configuration B−Test 2, illustrated in Table 15, provides an example of how the PCI BIOS discovers new controller devices that were not present in the original Test 1 configuration and how it assigns bus numbers during the discovery process. As in Test 1, the PCI BIOS moves through the bus detection order looking for controller devices (not the slot numbers). In this example, the PCI BIOS begins at the Host Bus and assigns bus 0 to the Primary Bus. Controllers that do not contain a bridge receive the bus number assignment of the bus on which it resides. In this scenario, the Netelligent 10/100 TX Controller in slot 3 does not have a bridge so it receives a bus assignment of bus 0. The PCI BIOS continues to search for the next device downstream on the Primary Bus. Two bridged controllers were added to the configuration. The PCI BIOS upon discovery of each controller assigns a bus number to the PCI bus on the bridged controller. Slot 4 now contains a SMART-2/P Drive Array Controller on bus 1 and slot 5 now contains a Dual 10/100TX PCI UTP Controller on bus 2.

With the addition of these two new controllers in the system, all other controllers that are discovered by the PCI BIOS after slot 5 in the discovery process are now assigned a new bus number. The SMART-2/SL Drive Array Controller in slot 6, a bridged device, is discovered next. The PCI BIOS assigns bus 3 to the PCI bus on the controller, which changes the original bus number assignment. This is also the last PCI controller discovered on the Primary Bus.

At this point, all bus number assignments on the Secondary Bus change when the PCI BIOS discovery process continues. The Secondary Bus is assigned bus 4. The controllers downstream on the Secondary Bus in slots 8 and 10 both contain bridges. Bus number assignments are made to the PCI buses on these bridged controllers. The SMART-2/SL Drive Array controller in slot 8 is assigned bus 5 and the Netelligent Dual 10/100 TX controller in slot 10 is assigned bus 4. Empty slots are ignored, because they do not contain PCI devices.

Comparison of Test 1 to Test 2 - Configuration B

When you reboot the server and run the System Configuration utility to view the hardware configuration changes, it displays slot and bus number assignments. Test 2 data was recorded and compared to Test 1.

A side-by-side comparison of the slot configurations and bus numbers of each device in Test 1 to the slot configurations and bus numbers of each device in Test 2, illustrates what bus numbers were changed after modifications took place.

Slot	Controller	Test 1	Test 2	Bus Assignment
Slot 3	Netelligent 10/100 TX (non-bridged)	✓	✓	Bus 0 - No Change
Slot 4	SMART-2/P Drive Array (bridged)		✓	Bus 1 - New
Slot 5	Netelligent Dual 10/100 TX (bridged)		✓	Bus 2 - New
Slot 6	SMART-2/SL Drive Array (bridged)	✓	✓	Bus 1 to Bus 3 - Changed
Slot 7	Empty			N/A
Slot 8	SMART-2/SL Drive Array (bridged)	✓	✓	Bus 3 to Bus 5 - Changed
Slot 9	Empty			N/A
Slot 10	Netelligent Dual 10/100 TX (bridged)	✓	✓	Bus 4 to Bus 6 – Changed
Slot 11	Empty			N/A

Appendix C, Reestablishing Network Connections on Retired Compaq ProLiant Servers

The following section describes one Compaq utility that provides assistance in verifying connections and reestablishing network links.

Compaq TLAN Network Teaming and Configuration Utility

This utility, a network-monitoring tool that provides a method of resetting network controllers and NetFlex-3 drivers when modifications are made to controller slot installation(s), displays PCI bus numbers, bus type, and slot numbers associated with each device.

Access the applet from the Windows NT Control Panel; the icon is labeled Compaq NetFlex. This utility is installed from the Compaq Support Paq for Microsoft Windows NT 4.0, if the system contains Compaq ThunderLAN-based network controllers.

The following table lists supported Compaq Netelligent and NetFlex-3 NICs for the Compaq TLAN Teaming and Configuration Utility:

Table 16. Supported TLAN NICs

TLAN Stand Up NICs	TLAN Embedded NICs
NetFlex 3 EISA	IC, SM,TLAN 10/100,REV3.03,TQF
NetFlex 3 100Base-TX Module	IC, SM,TLAN 10/100,REV3.03PQFP
NetFlex 3/P PCI UTP-BNC	IC, SM, TLAN 3.14 TQFP
Netelligent 10/100 TX PCI UTP	IC, SM,10/100TLAN 2.3,OPT
Netelligent 10 T PCI UTP	
Netelligent Dual 10/100 TX PCI UTP	
NetFlex 3 100Base FX Module	
Netelligent 10 T/2 PCI UTP/Coax	
NetFlex 3/P PCI UTP-BNC	

Visit the Compaq website for a complete list of supported controllers at http://www.compaq.com/products/networking/nics/.

This utility is packaged in the Smart Component called Compaq NetFlex/Netelligent Adapter Driver, which is available as an individual component and within the Compaq Support Paq on the Compaq SmartStart and Support Software CD and on the Compaq website at http://www.compaq.com/support/files/server/us/index.html.

Appendix D, Order of Detection for Retired Compaq ProLiant Servers

Table 17 lists the PCI bus detection order, Primary and Secondary bus locations, and slot numbers for the several retired ProLiant servers. This matrix can help you identify how the PCI BIOS assigns bus numbers in these servers. The ProLiant 2500 servers consist of the bridged PCI Bus architecture, and all of the others are dual-peer PCI Bus architecture servers. In reviewing this matrix you will see that there are differences in the PCI bus number detection order from one server model to another.

Table 17. PCI Bus number order of detection matrix

Bus	Bridged PCI Buses	Dual-Peer PCI Buses				
Detect/ Order Controller Discovery	ProLiant 2500	ProLiant 1200/ ProLiant 1600	ProLiant 3000/ ProLiant 5500	ProLiant 5000	ProLiant 6000/ ProLiant 7000	ProLiant 6500
1st	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge	Primary Host to PCI Bridge
2nd	PCI-to-PCI Bridge	Slot 4 – Pri Bus	Slot 1 - Pri Bus	Slot 5 - Pri Bus	Slot 3 – Pri Bus	Slot 1 – Pri Bus
3rd	Slot 6 - Sec Bus	Slot 5 - Pri Bus	Slot 2 – Pri Bus	Slot 8 – Pri Bus	Slot 4 – Pri Bus	Slot 2 – Pri Bus
4th	Slot 5 - Sec Bus	Slot 6 - Pri Bus	Slot 3 – Pri Bus	Slot 7 – Pri Bus	Slot 5 – Pri Bus	Secondary Host to PCI Bridge
5th	Slot 4- Sec Bus	Secondary Host to PCI Bridge	Slot 4 - Pri Bus	Slot 6 – Pri Bus	Slot 6 – Pri Bus	Slot 3 – Sec Bus
6th	Slot 3 - Pri Bus	Slot 1 - Sec Bus	Secondary Host to PCI Bridge	Secondary Host to PCI Bridge	Secondary Host to PCI Bridge	Slot 4 – Sec Bus
7th	Slot 2 - Pri Bus	Slot 2 - Sec Bus	Slot 5 – Sec Bus	Slot 4 – Sec Bus	Slot 7- Sec Bus	Slot 5 – Sec Bus
8th	Slot 1 - Pri Bus	Slot 3 - Sec Bus	Slot 6 – Sec Bus	Slot 3- Sec Bus	Slot 8 – Sec Bus	Slot 6 – Sec Bus
9th			Slot 7 – Sec Bus	Slot 2 - Sec Bus	Slot 9 – Sec Bus	Slot 7 – Sec Bus
10th			Slot 8 - Sec Bus		Slot 10 – Sec Bus	Slot 8 - Sec Bus
11th					Slot 11 - Sec Bus	

Primary Bus = Pri Bus; Secondary Bus = Sec Bus