Citrix XenServer Design: Configuring Multipathing for XenServer
## Contents

About................................................................................................................................................................... 5

Prerequisite Knowledge ....................................................................................................................................... 5

Visual Terminology Legend .......................................................................................................................... 6

Additional Terminology ................................................................................................................................ 7

Chapter 1: Introduction to Multipathing........................................................................................................ 8

Understanding Linux Multipathing ......................................................................................................... 9

Establishing Multiple Active Links to a LUN ........................................................................................ 9

Chapter 2: Introduction to iSCSI Multipathing .......................................................................................... 12

Creating Redundancy for iSCSI Storage Traffic ...................................................................................... 12

Multipathing iSCSI Storage Traffic ........................................................................................................... 14

Task Overview .............................................................................................................................................. 15

Preparing your Physical Environment ...................................................................................................... 16

Correct Subnet Configuration ................................................................................................................ 16

Switch Configuration ................................................................................................................................... 17

Prerequisite Tasks on the XenServer Host .............................................................................................. 18

Assign IP Addresses to NICs (Creating Secondary Interfaces).............................................................. 18

Retrieving and Changing the IQN in a XenServer Host ........................................................................ 21

Verifying that the iSCSI Target Ports are Operating in Portal Mode .................................................... 22

Checking for Multiple Targets on the Array ........................................................................................ 23

Chapter 3: Configuring Multipathing for iSCSI Hardware ........................................................................ 24

Overview of iSCSI HBA Multipathing..................................................................................................... 24

Task Overview .............................................................................................................................................. 25

XenServer HBA Support ........................................................................................................................ 26

Configuring iSCSI HBAs for multipathing .......................................................................................... 26
Adding a Persistent Target to the HBA Ports ............................................................................................ 29

Chapter 4: Configuring Fibre Channel Multipathing ..................................................................................... 33

Introduction to Fibre Channel Multipathing .............................................................................................. 33

Task Overview ............................................................................................................................................... 35

Configuring the Fibre Channel Ports as Targets .......................................................................................... 35

Retrieving the WWPN for an HBA using XenCenter .................................................................................... 36

Configuring the Switches for Fibre Channel Multipathing ........................................................................... 37

Chapter 5: Enabling Multipathing .................................................................................................................. 39

Overview ..................................................................................................................................................... 39

Editing the Multipath.conf File .................................................................................................................... 40

Multipath Handler Support: DM-MP, MPP RDAC, and DMP RDAC ....................................................... 45

Enabling Multipathing ................................................................................................................................. 47

Chapter 6: Creating the Storage Repository .................................................................................................. 49

Understanding Target IQNs for iSCSI Multipathing .................................................................................. 49

Chapter 7: After Enabling Multipathing ...................................................................................................... 55

Verifying Multipathing is Working Correctly ............................................................................................... 55

Additional Tasks ......................................................................................................................................... 56

Appendix A: Troubleshooting ....................................................................................................................... 57

Using Multipathing CLI Commands ............................................................................................................ 57

Displaying Paths in Use ................................................................................................................................. 58

Increasing the Number of Errors Captured in the System Log for Multipathing ....................................... 58

MPP RDAC Testing and Troubleshooting Commands ................................................................................. 58

Appendix B: Asymmetric Logical Unit Access (ALUA) .............................................................................. 60

Overview .................................................................................................................................................... 60

General Requirements ................................................................................................................................. 61
This document helps you understand how to configure multipathing for XenServer. It includes the following topics:

- An overview of XenServer multipathing
- Instructions for configuring software initiator iSCSI, Host Bus Adapter (HBA) iSCSI, and Fibre Channel protocol multipathing
- Some brief troubleshooting information

Due to scope, this guide provides very little device-specific information. For device-specific configuration, Citrix suggests reviewing the storage vendor’s documentation and the storage vendor’s hardware compatibility list as well as contact the vendor’s technical support if necessary.

Prerequisite Knowledge

While this guide provides some multipathing basics, it assumes you know the following:

- Basic storage concepts, such as “what is a LUN.”
- XenServer basics, such as the purpose of a Storage Repository (SR) and how to configure one.
- Basic configuration information for your storage array, such as how to add IQNs to a LUN, or where to find such information. Because this guide is not specific to any one brand of storage, it does not provide array-side configuration instructions.
• Why you want to configure multiple physical paths (multipaths) to storage. For example, is your goal to configure two different physical paths to the storage or do you want to do something more complex like create a pair of high availability controllers?

Although it is not strictly necessary, you might find it helpful to have a basic overview of Linux DM Multipath technology — for example, by reading the Wikipedia entry for it or searching for introductory articles on the Internet. DM Multipath is the foundation of the XenServer multipathing technology.

You do not need to be a Linux expert to use this guide. However, it is helpful if you are comfortable running commands, editing configuration files, and using utilities, such as WinSCP, to upload files from Windows machines to the XenServer host.

**Visual Terminology Legend**

This guide relies heavily on diagrams to explain key concepts. These diagrams use the following icons:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Host" /></td>
<td><strong>Host.</strong> A XenServer host is the physical server on which the XenServer hypervisor is running.</td>
</tr>
<tr>
<td><img src="image" alt="NIC" /></td>
<td><strong>NIC.</strong> The physical network card (NIC) in your host.</td>
</tr>
<tr>
<td><img src="image" alt="Physical Switch" /></td>
<td><strong>Physical Switch.</strong> The device on a physical network that connects network segments together.</td>
</tr>
</tbody>
</table>
**Storage Array.** This icon represents a generic storage array with a LUN configured in it.

**Storage Controller.** This icon represents a storage controller on a storage array.

---

**Additional Terminology**

These terms appear in the sections that follow:

**Management Interface.** The management interface is a NIC assigned an IP address that XenServer uses for its management network, including, but not limited to, traffic between hosts, between a host and Workload Balancing and for live migration.

**VM traffic.** VM traffic refers to network traffic that originates or terminates from a virtual machine. This is sometimes referred to as guest traffic or VM/guest traffic.

**Note:** In the XenServer 6.1 release, the term for primary management interface changed to the management interface. The term for a NIC with an IP address on it, a management interface, changed to secondary interface.
Chapter 1: Introduction to Multipathing

This guide provides general information about configuring multipathing with several different storage protocols, including iSCSI software initiator, iSCSI HBA, and Fibre Channel. This chapter provides information about the following:

- An introduction to multipathing
- An overview of Linux multipathing
- How XenServer establishes multiple active links to a LUN

For some audiences, the information in this chapter may be unnecessary. However, this information is given to provide a common baseline of information and avoid pitfalls that result from common misconceptions about iSCSI software initiator multipathing.

Introduction to XenServer Multipathing

XenServer provides support for configuring multiple data paths, or multipathing, to storage arrays.

Configuring multipathing helps provide redundancy for network storage traffic in case of partial network or device failure. The term multipathing refers to routing storage traffic to a storage device over multiple paths for redundancy (failover) and increased throughput.

XenServer multipathing configuration varies according to the storage protocol, storage vendor, and goals (for example, redundant controllers). This guide provides basic configuration information for each protocol.

Note: XenServer supports multipathing unless otherwise noted in the XenServer Hardware Compatibility List.
Understanding Linux Multipathing

In order to understand the issues potentially associated from misconfiguring multipathing, it is important to know the purpose of multipathing, the function of the DM-MP handler in Linux, and how hosts establish links with storage repositories.

As previously stated, multipathing is a method of providing redundant access to storage devices if one or more components between the XenServer host and the storage array fail. (Multipathing protects against connectivity failures and not storage device failures.)

Multipathing creates multiple connections between the XenServer host and the storage controller; these connections are known as paths. When organizations configure multipathing, they are configuring multiple paths to a storage device (LUN) on a storage subsystem.

DM-MP multipath handler

XenServer support for multipathing is performed by using the Linux native multipathing (DM-Multipath), which is part of CentOS. DM-Multipath (DM-MP) is the Linux module XenServer uses to provide multipathing functionality.

The primary purpose of the DM-MP handler is that it creates a storage device for each LUN instead of creating a storage device for each path. That is, DM-MP reconciles multiple paths to a LUN so that Linux only creates one storage device in spite of seeing multiple paths.

Without DM-MP, Linux would create a storage device for each path to a LUN. This means in an environment with two paths to a LUN, Linux would create two storage devices. This would make it difficult to specify a storage device or find the path to that device.

However, for Linux to establish multiple active links, or sessions, to a LUN, Linux must use DM-MP so that it can treat multiple paths as representing only one LUN yet still be able to recognize both paths.

Using multipathing requires support in the array for DM-Multipath, which varies by array vendor.

The DM-MP handler, as well as support for MPP RDAC and DMP RDAC, are described in more depth in “Multipath Handler Support: DM-MP, MPP RDAC, and DMP RDAC” on page 45.

Establishing Multiple Active Links to a LUN

For a XenServer host to establish a link with the storage repository, it must, using iSCSI terminology, create a target and initiator connection. XenServer, the initiator, does so by querying the storage device, the target, and waiting for the target to reply saying it is available. After XenServer receives a list of target IQNs, XenServer, in its role as initiator, logs into the target. The target now has a link for sending traffic.
This illustration shows the process for creating a session. (1) XenServer, in its role as initiator, queries the storage target for a list of IQNs; (2) the storage device (target) responds with the list; and (3) after receiving the IQN list, XenServer establishes a session with the target.

This link (the session) remains up and only needs to be established if there is a reboot. After you configure both paths to the storage array (the multipath) and two paths are created, XenServer can create a session for each link, as shown in the following illustration.

This illustration shows how when multipathing is enabled XenServer creates two sessions with the storage target.

The multipath handler uses target IQNs to determine if the storage devices discovered on the target are different LUNs or different paths. The handler makes this determination by querying the storage target. The target replies with the IQN, which includes the LUN serial number. (Ideally, regardless of the number of paths connecting to a LUN, the serial number in the IQN is always the same.)

The multipath handler checks IQNs for matching serial numbers to determine how many paths are associated with each LUN. When the serial numbers in the IQNs match, the handler assumes that the IQNs are associated with the same LUN and therefore must represent different paths to that LUN.
When you create the storage repository and multipathing is enabled (specifically, when you create the Physical Block Device (PBD)), XenServer includes a `multihome` parameter that resets XenServer to expect a multihomed device. (The term multihome refers to computer or, in this case, a storage device that has multiple IP addresses connected to a network.)

If XenServer is not aware the storage device is multihomed (because multipathing was not enabled before the PBD/storage repository was created), XenServer can only create one session (or path) to the array.

For iSCSI arrays, it is better to configure multipathing first; however, if you created the storage repository first, you can put the host into maintenance mode and then configure multipathing. (For Fibre Channel, Citrix strongly recommends configuring multipathing and enabling the multipathing check box in XenCenter before creating the storage repository.)

With all types of SANs, it is best to plan and design your storage and networking configuration before implementation, determine you want multipathing, and configure it before putting the pool into production. Configuring multipathing after the pool is live results in a service interruption: configuring multipathing affects all VMs connected to the storage repository.

**XenServer Multipathing Implementation**

To provide multipathing functionality, XenServer uses a module from the Linux operating system. The module is a Linux configuration file that tells XenServer to reference specific portions of code.

However, each storage vendor on the XenServer Hardware Compatibility list defines device-specific multipathing settings that XenServer needs to communicate over multiple paths with the storage array. These settings are contained in a configuration file that is stored on the XenServer host, which is known as multipath.conf.

For some storage arrays, enabling multipathing is as simple as merely clicking the check box in XenServer. For other arrays, it requires using a non-default multipathing handler (handlers are essentially like drivers) and changing the settings in multipath.conf.
Chapter 2: Introduction to iSCSI Multipathning

This chapter provides an introduction and high-level steps for configuring iSCSI multipathing support. It includes the following topics:

- An overview of the importance of redundancy for software initiator iSCSI storage traffic
- Steps for configuring multipathing for iSCSI software initiator storage devices, including how to check if the target ports are operating in portal mode
- An overview of how to prepare your physical environment, including correct subnet and switch configuration

Creating Redundancy for iSCSI Storage Traffic

When configuring redundancy for iSCSI software initiator storage traffic, you can choose between NIC bonding and multipathing. While NIC bonding can also provide redundancy for storage traffic, Citrix recommends configuring multipathing instead of NIC bonding whenever possible.

When you configure multipathing, XenServer can send traffic down both paths: multipathing is an active-active configuration. (By default, multipathing uses round-robin mode load balancing, so both routes will have active traffic on them during normal operation, which results in increased throughput.)

XenServer 6.1 provides active/active, active/passive, and LACP bonding support. However, none of these configurations support active/active storage traffic. (Active/active bonding is only active on both links for guest traffic, as described in the XenServer Administrator's Guide.)
Citrix recommends configuring multipathing whenever possible for the following reasons:

- Multipathing can extract the path priorities from the array, which is valuable for redundant controller configurations such as ALUA.

- Some arrays must be sent specific commands to reconfigure the controllers to cause a failover. (In the multipath.conf file, the hardware_handler setting indicates how to do this.)

- You can configure multipathing to perform round-robin load balancing within a priority group, with a configurable number of I/O requests on each path before going to the next. Some arrays require this configuration to coalesce requests for performance reasons. LACP bonding may send all the traffic down a single link because LACP bonding relies on different endpoints and the endpoints are fixed in this case.

The likelihood of LACP bonding matching the performance and load balancing of multipathing for storage traffic varies on an array-by-array basis. For the previously mentioned reasons, Citrix suggests considering a multipathing configuration instead of LACP bonding for storage traffic whenever possible. The illustration that follows provides a visual guide to the differences.

This illustration shows how, for storage traffic, both paths are active with multipathing. LACP bonding enables four active NICs; however, only one path is active for storage traffic unless you configure multipathing.
Citrix strongly recommends that you do not mix NIC bonding and iSCSI multipathing. There is no benefit from layering multipathing and NIC bonding on the same connection. After you enable multipathing, you not only have better performance but you also have the failover that bonding would have provided.

Multipathing is incompatible with the following technologies, so you should consider using NIC bonding when:

- You have an NFS storage device.
- Your storage device does not support iSCSI connections over multiple IPs (for example, Dell EqualLogic or HP LeftHand SAN).
- You have limited number of NICs and need to route iSCSI traffic and file traffic (such as CIFS) over the same NIC.

For more information about choosing NIC bonding or multipathing, see *Designing XenServer Network Configurations*.

**Tip:** To determine what XenServer hosts have multipathing enabled on them, see *Multipathing* on the *General* tab in XenCenter.

### Multipathing iSCSI Storage Traffic

For iSCSI software initiator storage traffic, it is important to consider redundancy. The iSCSI protocol was not designed for failure, resending packets, or data loss. Consequently, resiliency is very important. If there is a hardware issue with an iSCSI storage component, the throughput will be poor.

When working with iSCSI, it is important to design the infrastructure to be solid enough to support I/O. Ideally, iSCSI storage traffic should be sent over a separate physical network to prevent issues at the Ethernet level. If there are issues at the Ethernet level, storage transactions will be a problem.

Likewise, it is recommended that you use high quality switches that are on your storage vendor’s hardware compatibility list and have been tested with your storage array.

When configuring iSCSI software initiator multipathing, there are two major points to consider:

- The type of multipath handler your array supports.
- Whether your array returns just one iSCSI Qualified Name (IQN) or multiple IQNs.

If you enable multipathing, you must do so on all hosts in the pool.
Task Overview

When configuring iSCSI software initiator multipathing, perform the following:

1. Create the redundant physical paths (that is, set up the cables, switches, and subnets before configuring any storage settings in XenServer, including creating your storage repository), as described in “Preparing your Physical Environment” on page 16. This may include:
   a. Correct Subnet Configuration—see page 16
   b. Switch Configuration—see page 17

2. Performing tasks on each XenServer host in the pool:
   a. Assign IP addresses to NICs, as described in “Assign IP Addresses to NICs (Creating Secondary Interfaces)” on page 18.
   b. Obtain and note the IQNs on the XenServer host, as described in “Retrieving and Changing the IQN in a XenServer Host” on page 21.
   c. Ensuring iSCSI ports are targets, as described on page 22.

3. Configuring the storage array:
   a. On each controller on the storage array, put one of the NICs on one of those subnets. (For example, make sure that on Controller A, NIC 1 is on Subnet 1 and NIC 2 is on Subnet 2. Likewise, on Controller B, make sure that NIC 1 is on Subnet 1 and NIC 2 is on Subnet 2.)
   b. Enabling the array so that it can accept XenServer iSCSI initiators by providing it with the XenServer IQNs (for example, creating an initiator group on a NetApp).
   c. Follow any vendor multipathing configurations specific to your storage device.
   d. Create any logical disks (such as LUNs or, in the case of the Dell EqualLogic, volumes) required.

   Note: These tasks are beyond the scope of this guide. For more information about these tasks, see your storage vendor’s documentation.

4. Enabling multipathing and creating the SR on each XenServer host in the pool.
   a. Selecting the correct multipath handler as described on page 40.
   b. Editing the multipath.conf file (if necessary).
   c. Enabling multipathing in XenCenter (or using the CLI, if desired).
d. Creating the SR. (If you select the pool node in XenCenter when you create the SR, you only need to create the SR once.)

After performing these tasks, you must also enable multipathing in XenCenter before creating the SR.

Preparing your Physical Environment

Create the redundant physical paths (that is, set up the cables, switches, and subnets) before configuring any storage settings in XenServer, including configuring multipathing and creating your storage repository.

This section provides information about the following:

- Correct subnet configuration for multipathing
- Switch configuration for iSCSI multipathing

Correct Subnet Configuration

A typical multipathed configuration requires two different subnets:

- A subnet that connects port A on each host to storage controller 1
- A different subnet that connects port B on each host to storage controller 2

This means you will need a total of four IP addresses plus two more for each host.

Specifically, one NIC on each storage controller must be on the same subnet as each storage NIC on the XenServer host. For example, in the illustration that follows, which depicts multipathing with two switches, XenServer NIC 1 is on the same subnet as NIC1 on Storage Controller 1 and NIC 1 on Storage Controller 2.
This illustration shows how both NICs on the host in a multipathed iSCSI configuration must be on different subnets. In this illustration, NIC 1 on the host along with Switch 1 and NIC 1 on both storage controllers are on a different subnet than NIC2, Switch 2, and NIC 2 on the storage controllers.

Also, every host in your pool must have a matching (parallel) networking configuration. This means that if you configured NIC2 as Secondary Interface 1 on the 10.204.150.x subnet, then you must configure every NIC2 on each host in your pool to use that same subnet and carry storage traffic to the same controller. For example, for NIC 2:

Important: Do not route iSCSI storage traffic through the XenServer host’s management interface.

Tip: XenCenter lets you configure all secondary interfaces in the pool simultaneously. To do so, select the pool node in XenCenter and create the secondary interface on the first host in the pool a static IP address and then let DHCP assign the corresponding NICs on the other hosts their IP addresses. For more information, see Designing XenServer 6.1 Network Configurations.

Switch Configuration

Setting up your storage solution correctly, including switch configuration, is critical for multipathing success.

The best-practice recommendation for failover is to use two switches; however, even if you do not configure two switches, you must logically separate the paths (that is, put each NIC on the host on separate subnets). Because TCP/IP acts as the transport protocol for iSCSI storage traffic, correct IP configuration is essential for iSCSI multipathing to work.
Prerequisite Tasks on the XenServer Host

This section summarizes tasks that you perform on or from the XenServer host before you enable multipathing, such as:

- Creating secondary interfaces (assigning IP addresses to NICs) so a storage controller can connect to XenServer.
- Retrieving or editing the IQNs in a XenServer host
- Verifying that the iSCSI target ports are operating in portal mode and checking for multiple targets on the array

Assign IP Addresses to NICs (Creating Secondary Interfaces)

To connect a storage controller to a XenServer NIC, the NIC must have an IP address. While you can re-use the management interface for one of the NICs, the best practice is to configure two (additional) secondary interfaces. (A secondary interface is a NIC with an IP address assigned to it, which is typically so a storage controller can communicate with XenServer, but it can also be used for other purposes).

Any secondary interfaces you create for storage must be on a different subnet than the management interface. Likewise, secondary interfaces cannot be on the same subnet as each other. For example, if you want to configure two secondary interfaces for storage, XenServer requires IP addresses on three different subnets – one subnet for the management interface, one subnet for Secondary Interface 1, and one subnet for Secondary Interface 2.

There are two different techniques for assigning IP addresses to NICs in XenCenter:

- You can assign a static IP address to a NIC on each host.
- You can use XenCenter to assign dynamic IP addresses, based off of a static IP, to all corresponding NICs on all hosts in the pool.

In both cases, you must assign the IP address to the same (corresponding) NIC on each host. For example, if you create an IP address on NIC 3, you must configure an IP address from the same subnet to NIC 3 on all hosts in the pool. (In the second method, XenServer automatically assigns the IPs to the corresponding NICs for you.)

Assigning Static IP Addresses

You can assign a static IP address to a NIC using XenCenter. Depending on the XenServer release, this functionality is known by various names, including creating management interfaces, storage
management interfaces, and secondary interfaces. The instructions for this task may vary according to your release. For instructions specific to your release, see the XenCenter Help.

To assign a static IP address to a NIC

1. Ensure that the NIC is on a separate subnet, or routing is configured to suit your network topology in order to force the desired traffic over the selected NIC.

2. In the Resource pane of XenCenter, click on the pool (or standalone server). Click the Network tab, and then click the Configure button.

3. In the Configure IP Addresses dialog, in the left pane, click Add IP address.

4. Give the new interface a meaningful name, and select the Network associated with the NIC where you want to configure the storage management interface (for example, “Secondary Interface for Storage”).

5. Select Use these network settings, and enter a static IP address you want to configure on the NIC, the subnet mask, and gateway, and click OK.

   The IP address you enter must be in the same subnet as the iSCSI storage management controller to which you will ultimately be connecting the NIC.

Assigning Dynamic IP Addresses Simultaneously

A simple way to assign IP addresses to NICs across a pool is to assign the NIC on the first host in the pool a static IP address and then let DHCP assign the corresponding NICs on the other hosts their IP addresses.

After you specify the static IP address, XenServer automatically creates a secondary interface on the corresponding NICs on each host and sets them to use the next available IP address, as shown in the illustration that follows.
This illustration shows how after an administrator created a management interface on NIC 3 on Host 1 and set it to 10.204.150.44, XenServer automatically created secondary interfaces on the other hosts in the pool and set their IP addresses using DHCP. Each host in the pool is assigned the next IP address in the range—Host 2 is set to 10.204.154.35, Host 3 is set to 10.204.154.36, and Host 4 is set to 10.204.154.37.

Important: If you are configuring IP addresses on NICs to connect to an iSCSI storage controller, the static IP address you enter must be in the same subnet as the storage controller to which you will ultimately be connecting the NIC.

The following procedure explains this technique.

**To assign all corresponding NICs in a pool an IP address**

1. Ensure that the NICs are on a separate subnet, or routing is configured to suit your network topology in order to force the desired traffic over the NICs.
2. In the Resource pane of XenCenter, click on the pool. Click the Network tab, and then click the Configure button.
3. In the left pane, click Add IP address.
4. Give the NIC a meaningful name, and select the Network associated with the NIC where you want to assign the IP address. An example of a meaningful name might be “Storage Network 1” or “your-storage-controller-name-or-model 2.” Numbering your storage management interfaces will make it easier to configure multipathing, if desired, later on.

   If you want to assign the IP address on NIC 3, for example, select the network associated with NIC 3.

5. Select Use these network settings, and enter a static IP address you want to configure on the first NIC, the subnet mask, and gateway, and click OK.

   The range of IP addresses XenServer will use to configure the corresponding IP addresses in the pool appears to the right of the IP address you entered.

   After you click OK, XenServer assigns the IP addresses to the NICs. When you click the Pool node in the Resource pane, the new secondary interfaces appear in the IP Address Configuration section of the Networking tab.

Retrieving and Changing the IQN in a XenServer Host

XenServer automatically generates a different IQN for each host that is valid for use when creating iSCSI initiator groups. However, depending on the naming conventions in your organization, you may want to change this IQN.

Even if your organization does not have naming conventions, including the host name or other meaningful information makes it easier to know what IQNs are associated with what hosts when you are configuring the array.

   Important: Make sure the iSCSI target and all servers in the pool do not have the same IQN set. It is imperative that every iSCSI target and initiator have a unique IQN. If a non-unique IQN identifier is used, data corruption can occur and/or access to the target may be denied.

To create a new IQN in XenCenter (optional)

1. In the XenCenter Resource pane, select the host.
2. Click the General tab.
3. Click Properties.
4. In the properties dialog that appears, select the General tab, and modify the name of the IQN to match your organization’s naming conventions.
To retrieve the IQN from the XenServer host

1. In the XenCenter Resource pane, select the host.
2. Click the General tab.
3. Right-click the IQN, and select Copy to copy the IQN to your clipboard.

Verifying that the iSCSI Target Ports are Operating in Portal Mode

Before you enable multipathing and create the SR, verify the iSCSI target ports are operating in portal mode.

To verify that the iSCSI target ports are operating in portal mode

1. Verify that the iSCSI target ports are operating in portal mode:
   
a. In XenCenter, start the New Storage Repository wizard (Storage menu > New Storage Repository).
   
b. Click through the options until you reach the Enter a name and path for the new iSCSI storage page, click Discover IQNs. XenServer queries the storage for a list of IQNs.
c. Check the **Target IQN** list box on the **Location** page of the Storage Repository Wizard.

If the iSCSI target ports are operating in portal mode, all target IPs should show up on the **Location** page of the Storage Repository Wizard.

### Checking for Multiple Targets on the Array

Before attempting to enable multipathing, verify that multiple targets are available on your storage server. For example, an iSCSI storage backend queried for **sendtargets** on a given portal should return multiple targets, as in the following example:

```
iscsiadm -m discovery --type sendtargets --portal 192.168.0.161

192.168.0.161:3260,1 iqn.strawberry:litchie
192.168.0.204:3260,2 iqn.strawberry:litchie
```
Chapter 3: Configuring Multipathing for iSCSI Hardware

This chapter provides information about configuring multipathing for iSCSI HBA SRs and includes the following topics:

- Configuring an HBA for the iSCSI protocol
- Adding a persistent iSCSI target to the HBA ports
- Enabling multipathing
- Creating an iSCSI SR over HBA

This chapter provides an example of how to create an iSCSI hardware SR using a QLogic HBA as an example. If your HBA is from another vendor, use this example as a general guide, but use an HBA configuration utility from your HBA vendor and follow their instructions for configuring the HBA.

Overview of iSCSI HBA Multipathing

When you want to configure multipathing for an iSCSI hardware SR, you must specify a persistent iSCSI target on each HBA. Like software initiator iSCSI, the HBA ports and the storage controller ports must be on different subnets.

The best-practice recommendation for failover is to use two switches; however, even if you do not configure two switches, the physical networks associated with the HBA ports being multipathed must be on different subnets. For example, if HBA port 1 connects to Network 1 and HBA port 1 and HBA port 2 are being multipathed, then HBA port 1 and HBA port 2 must be on different subnets.

The following illustration shows how the HBA ports are on different subnets.
This illustration shows how both HBA ports on the host in a multipathed iSCSI configuration must be on different subnets. In this illustration, HBA port 1 on the host along with Switch 1 and NIC 1 on both storage controllers are on a different subnet than HBA port 2, Switch 2, and NIC 2 on the storage controllers.

This means that you must be aware of the separate subnet requirement from the time you configure the IP addresses for the HBA ports and IP addresses on the storage controllers to when you set the persistent iSCSI target (mask the LUN).

When you are configuring an iSCSI HBA SR, you must make the HBA aware of the storage controller and restrict the LUN so that it cannot accept connections from any other hosts other than the HBAs you specify (through LUN masking).

This means that you need to create a persistent iSCSI target on each port on the HBA (by providing each port on the HBA with the IQNs from the storage controller). You may also need to provide the IQNs from the HBA ports to the storage array.

**Note:** In order to use an HBA for iSCSI storage, XenServer must detect the HBA as an iSCSI port, as described on page 22.

**Task Overview**

Before you can create a multipathed iSCSI hardware SR, you must install the HBA and configure it. This section explains the process from a high level.

1. Configure the HBA on each host.
   a. Set the IP networking configuration for each port on the HBA.
b. Add a persistent iSCSI target to each port of the HBA.

c. Rescan the HBA controller to display the available LUNs.

d. If you need to provide the array the IQN from the HBA, note it. If an IQN is not already set on the HBA, you might need to configure an IQN for the HBA: in this case, see the HBA vendor’s documentation.

2. Potentially perform array-side tasks, such as using the IQNs to provide access and creating a LUN. Such tasks are beyond the scope of this guide; see your storage vendor’s documentation.

3. Verify that iSCSI target ports are operating in portal mode as described on page 22.

4. Check there are multiple iSCSI targets on the array as described on page 23.

5. Enable multipathing as described in “Chapter 5: Enabling Multipathing” on page 39.

6. Create the HBA SR as described in “Chapter 7: After Enabling Multipathing” on page 55.

XenServer HBA Support

XenServer supports the several different brands of HBAs, as listed in the storage controllers section of the XenServer Hardware Compatibility List (http://hcl.xensource.com/HCLHome.aspx). However, each XenServer host contains utilities for configuring the following HBAs:

- **QLogic.** XenServer includes the iscli command, which is found at /opt/QLogic_Corporation/SANsurferiCLI/iscli.

- **Emulex.** XenServer includes the hbanywhere utility, which is found at /usr/sbin/hbanyware.

Access these utilities by running them from the CLI on the XenServer host.

**Configuring iSCSI HBAs for multipathing**

Configuring an iSCSI HBA for use with multipathing is a two-step process:

1. Set the IP networking configuration for the HBA. You can set either a static or DHCP IP address.

2. Add a persistent iSCSI target to each port on the HBA.

Because storage is a pool-wide feature, you need to perform these steps for each HBA you want to configure on each host in the pool.

As an example, this guide uses a QLogic iSCSI HBA and the CLI iscli command. If you are using an Emulex HBA or another brand on the XenServer Hardware Compatibility List, see the HBA’s documentation for the details of the HBA-side configuration.
To set the IP address for an HBA

1. On each XenServer host in the pool, set the IP address for the HBA by running the `iscli` CLI command:

   a. Choose option 4, then option 2 to enter **Port Network Settings Menu**.

   b. Enter option 4 to **Select HBA Port**.

   c. Type 1 or 2 to select the HBA port to which you want to assign the IP address.
d. Enter option 2 to Configure IP Settings.

c. Press Enter to enable IPv4 and configure the associated options.

f. After setting the options, be sure to select option 5 to save the changes.

2. Repeat this procedure for any additional ports on the HBA.

3. Repeat this procedure for the HBAs on the other hosts in your pool.

To obtain the IQN assigned to the HBA

1. Get the IQN of the ports of the iSCSI HBA from the output of iscli command.
Adding a Persistent Target to the HBA Ports

Before you can create an SR, you must add a persistent iSCSI target to the HBA on each host in the pool. This enables the newly created LUN to appear as an iSCSI device to the XenServer host.

The commands that follow force a scan of HBAs installed on the system and detect the new LUN zoned to the host. The commands will return properties for each LUN found. One of these properties will be <path> which is the global device path of the HBA LUN.

The following procedure provides an example of how to add a persistent target. The procedure assumes you want to enable multipathing and that you have two ports on the HBA or two HBAs.

To add a persistent iSCSI target to the HBA ports

1. Run the following command on a XenServer host, either using the console tab or a utility like putty. Specify the host-uuid of the system from where the xe sr-probe command is run.

   xe sr-probe type=lvmohba host-uuid=<UUID of host>

   Example:
   
   xe sr-probe type=lvmohba host-uuid=4580744e-1a9d-407c-af3c-bbb020488af2

2. Add a persistent iSCSI target to each HBA port.
   a. In the management console for your storage, for each controller, obtain the target iSCSI target node name.
b. **For HBA port 1:**

On the XenServer host, run the following command to add a persistent target for each storage controller to each HBA port. This command assigns the HBA port the specified iSCSI IP address and specific target IQN on the controller.

```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 <iSCSI_target_IP_address> -NAME
```

- `pa` adds a persistent target.
- `0` is the first HBA port number (1 is the second HBA port).
- `<iSCSI_target_IP_address>` is the IP address on the desired non-management NIC or e0a port (non-management port) of the storage controller.

`[-INAME]` is the iSCSI Target Node Name (that is, the IQN of the storage controller on the storage).

After running the commands, a screen like the following appears:

```
[root@localhost ~]# /opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 10.204.132.52 -INAME iqn.1992-08.com.netapp:sn.1574216687
Using config file: /opt/QLogic_Corporation/SANsurferiCLI/iscli.cfg
[root@localhost ~]#
```

**Example:**

To configure the first port (Port 0) on the HBA with the IQNs and IPs for both storage controllers in a multipathed configuration, you would run:

```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 10.204.132.52 -INAME iqn.1992-08.com.netapp:sn.1574216687

/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 10.204.150.54 -INAME iqn.1992-08.com.netapp:sn.1574216687

/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 10.204.132.82 -INAME iqn.1992-08.com.netapp:sn.1574216690

/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 10.204.150.84 -INAME iqn.1992-08.com.netapp:sn.1574216690
```

**Note:** If you do not want to enable multipathing, you would only run the commands for one of the storage controllers.
3. For HBA 2:

For HBAs with two ports (or a second one-port HBA), re-run this command:

```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 0 <iSCSI_target_IP_address> -NAME
```

Example:

To configure the second port (Port 1) on the HBA with the IQNs and IPs for both storage controllers, you would run:

```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 1 10.204.132.52 -INAME iqn.1992-08.com.netapp:sn.1574216687
```
```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 1 10.204.150.54 -INAME iqn.1992-08.com.netapp:sn.1574216687
```
```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 1 10.204.132.82 -INAME iqn.1992-08.com.netapp:sn.1574216690
```
```
/opt/QLogic_Corporation/SANsurferiCLI/iscli -pa 1 10.204.150.84 -INAME iqn.1992-08.com.netapp:sn.1574216690
```

Note: For multipathing, the above command was run for two of the iSCSI HBA ports, each port connecting to a different subnet. For more information about multipathing, see page 24.

4. Use the `xe sr-probe` command to force a scan of iSCSI HBAs installed on the system and detect the new LUN zoned to the host. It will return the list of properties for each LUN found. One of these properties will be `<path>` which is the global device path of the HBA LUN. Specify the host-uuid of the system from where the `xe sr-probe` command is run.

```
xe sr-probe type=lvmohba host-uuid=<UUID of host>
```

To validate that the device path is for the newly created LUN on the device, proceed to the next procedure and match the serial number from the `<serial>` field of the `xe sr-probe` output with the
serial number of the LUN in NetApp System manager. Note that there are two paths to the
LUN indicating that multipathing is active.
Chapter 4: Configuring Fibre Channel Multipathing

This chapter provides information about the following:

- An introduction to Fibre Channel multipathing
- A task overview to set up Fibre Channel multipathing
- How to configure the Fibre Channel Ports as targets
- How to retrieve the WWPN for an HBA using XenCenter

Introduction to Fibre Channel Multipathing

XenServer supports configuring multipathing for storage arrays on the XenServer Hardware Compatibility List that use the Fibre Channel protocol. Configuring multipathing for the Fibre Channel protocol enables XenServer to redirect traffic through another HBA port, switch, or controller in the event that one of these is no longer available.

Multipathing for Fibre Channel storage is generally between two HBAs on the XenServer host connecting to one or more switches in the SAN fabric to the controller on the array. If one of the switches fails, XenServer redirects traffic to the other switch in the fabric. This is shown in the illustration that follows.
In this illustration, Fibre Channel cables form two physical paths from each host to the controller. Cables connect each HBA connects to both switches and then to the storage controllers.

To manage multiple paths, XenServer uses the `multipath.conf` configuration file. The `multipath.conf` file provides configuration values XenServer requires to send storage traffic over multiple paths. The settings required vary according to settings specific to your array, and also whether you are failing over between controllers and the controllers use Asymmetric Logical Unit Access (ALUA) to manage the paths.

If your array requires ALUA, you may need to replace the device specific settings in `multipath.conf` with different settings for ALUA. For more information, see “Appendix B: Asymmetric Logical Unit Access (ALUA).” For more information about `multipath.conf`, see page 40.

**Minimum Requirements**

- Fibre Channel protocol configured
- 1-2 Fibre Channel switches (two switches is the best practice)
- Each host in the pool must have at least two Fibre Channel HBA ports (either (a) one HBA with two ports or (b) two HBAs with one port each)
Task Overview

At a high level, configuring multipathing for Fibre Channel requires the following tasks:

1. Setting up the physical equipment.
2. Retrieving the WWPNs from the HBAs on the XenServer host.
3. Configure the Fibre Channel switches so they zone in the LUNs to the relevant hosts (that is, all hosts in the pool) by creating zone-sets.
4. Configuring the storage array, including creating the LUN on the controller.
5. Configure storage on each XenServer host in the pool.
   a. Configuring at least two Fibre Channel ports as targets.
   b. Editing the multipath.conf file, if required.
   c. Enabling multipathing in XenCenter (or using the CLI, if desired).
   d. Creating the SR. (If you select the pool node in XenCenter when you create the SR, you only need to create the SR once.)

After performing these tasks, you must also enable multipathing in XenCenter before creating the SR.

Configuring the Fibre Channel Ports as Targets

For XenServer to connect to a Fibre Channel LUN over multiple paths, you must configure at least two of the Fibre Channel ports on the storage as the target. If the ports are not configured as targets, XenServer cannot detect them as it tries to connect to the storage when mapping the SR to the LUN.

*To configure the Fibre Channel ports on the controller as targets*

1. Connect to the controller using a utility such as Putty.
2. Run the `fcadminconfig` command to display if the ports on the controller are configured as initiators or targets.
3. If the ports are not already offline, run the following command to set them offline:

   ```
   fcadminconfig -d <adapter_name>
   ```
4. After you determine what port you want to configure as the target, run the `fcadminconfig -t <type> <adapter_name>` command. For example, to configure port 0c as the target, run:

`fcadminconfig -t target 0c`

5. To put the ports back online, run the following command:

`fcadminconfig -e <adapter_name>`

6. Repeat this process for the other Fibre Channel HBAs on the controllers.

### Retrieving the WWPN for an HBA using XenCenter

Before you can zone your Fibre Channel switch, you must retrieve the WWPNs for the HBAs on each XenServer host.

Run the following procedure from the CLI on a XenServer host to retrieve the WWPNs for its HBAs. This procedure uses the generic, vendor-agnostic `systool` command. However, if desired, you may be able to obtain WWPNs by running vendor-specific HBA utilities or utilities like HBAAnywhere.

For additional tips on finding WWPNs, see CTX118791--`Multipathing Overview for XenServer 5.0`.

*To retrieve the WWPN for an HBA*

1. On the XenServer host (for example, by using the **Console** tab in XenCenter), enter the following command at the command prompt:
systool -c fc_host -v |grep port_name

2. Look for the WWPNs beside **port_name**. For example:

```bash
[root@localhost ~]# systool -c fc_host -v |grep port_name
port_name = "0x10000000c9adbf06"
port_name = "0x10000000c9adbf07"
```

**Note:** When specifying the WWPN (for example, when you zone switches), omit the 0x from the port_name value. For example, for 0x10000000c9adbf06, enter 10000000c9adbf06.

**Configuring the Switches for Fibre Channel Multipathing**

To configure multipathing for Fibre Channel connections, you must use a Fibre Channel switch between the links and configure zones on those links. While the specific configuration varies by switch and manufacturer, at a high-level, you must do the following:

1. Create two zone-sets in the switch. For example, zone-set1 and zone-set2.

2. Add the following members to zone-set1:
   - The WWPN from controller 1.
   - The WWPN from controller 2.
   - The WWPN of HBA1.

3. Add the following members to zone-set2:
   - The WWPN from controller 1.
   - The WWPN from controller 2.
   - The WWPN of HBA2.
In this illustration, the WWPN from HBA1, controller1, and controller2 are added to zone-set1 in the switch. The WWPN from HBA2, controller1, and controller2 are added to zone-set2 in the switch.

After configuring the zones sets in the switches continue on to enable multipathing, as described in “Chapter 5: Enabling Multipathing” on page 39.
Chapter 5: Enabling Multipathing

This chapter provides information about the following topics related to enabling multipathing:

- XenServer support for the different multipathing handlers, such as DM-MP, MPP RDAC, and DMP RDAC, and guidance about when to use them
- Guidance about when you need to edit the multipath.conf file
- Directions for enabling multipathing in XenCenter
- How to enable the MPP RDAC handler

**Important**: Before enabling multipathing, check to see if there are instructions for your specific storage vendor—see “Vendor-specific Multipathing Documentation” on page 64.

**Overview**

Every array has unique requirements for how it can receive traffic over multiple paths. For XenServer to send traffic across multiple paths, you must configure the correct settings in each host.

Enabling multipathing is potentially a three-stage process that requires:

1. Editing multipath.conf, if required.
2. Changing the default multipathing driver (handler).
3. Enabling multipathing.

The process you use to enable multipathing varies according to your array model and your vendor’s requirements.
Before you enable multipathing, determine:

1. If you need to edit multipath.conf? XenServer provides some default settings; however, you may need to modify these based on your vendor’s recommendations as described in “Editing the Multipath.conf File” on page 40.

2. If you need to select and configure a different handler (other than the default DMP)? LSI-based arrays typically require the MPP RDAC handler, as described on page 40.

After you have made these decisions, then you can proceed to configure and then enable multipathing.

Note: Citrix recommends that you try to keep the number of associated LUNs with a specific XenServer host as small as feasible. For example, if the host needs access to ten LUNs, but there are an additional fifteen unused LUNs associated with the host (which are no longer needed), deleting the SRs for these LUNs will improve performance during discovery and creation.

**Editing the Multipath.conf File**

Citrix recommends that before you enable multipathing (for example, by clicking the Enable multipathing on this server) you check the multipath.conf file and compare the settings in the file to your vendor’s recommendations to determine if you need to change the file.

As previously discussed, multipathing settings are controlled through the multipath.conf file, which is a Linux configuration file that provides settings XenServer uses to communicate with its storage over multiple paths. XenServer uses this file is stored, which is stored on each host in /etc/multipath.conf, to find the code modules it needs to process multipathing traffic.

The multipath.conf file can control several different functions, including, for example, which arrays the file applies to, how XenServer should handle the paths, how it should perform load balancing, and which code modules it should reference.

In many cases, it is not necessary to edit the multipath.conf file and you can simply enable multipathing using XenCenter.

However, you may need to edit the multipath.conf file if the settings specific to your array are not included in the file. If your array is not listed in the file, but it is supported on the XenServer Hardware Compatibility List, contact your storage vendor for the configuration that should be used. In many cases, XenServer uses the same settings as the Red Hat Linux multipath configuration.

The settings contained in the file are specific to the storage supported in the XenServer Hardware Compatibility List.
To determine if you need to modify the settings, open the multipath.conf file on a XenServer host and compare its device settings to the settings for your array model in your vendor’s interoperability guide or the settings you receive from your vendor’s technical support.

The multipathing configuration file in XenServer 6.1 is based on the DM-Multipathing 0.4.7, which is part of Red Hat Linux 4.0, Update 3.

**Structure of the Multipath.conf File**

This section explains what you need to consider when verifying the multipath.conf file against your vendor’s settings. When verifying your settings, consider all sections, but pay particular attention to the defaults and devices sections.

Citrix has commented out many of the sections and settings in multipath.conf, including the blacklist section and the blacklist_exceptions section.

*Important:* Do not make changes to the multipath.conf file while multipathing is enabled.

Additional information about the sections in multipath.conf and how to edit them is available in the Red Hat documentation for CentOS-5 (for example, *Using Device-Mapper Multipath: Configuration and Administration*).

All changes that you make to the multipath.conf file need to be made to that file on each host in the pool.

**blacklist**

```bash
# Blacklist all devices by default. Remove this to enable multipathing on the default devices.
#blacklist {
#        devnode "*"
#}
```

- **Description.** The blacklist specifies device types to which the settings in the file would not apply. You can use this section if, for example, the XenServer hosts in your pool are connected to several different storage arrays but you have not configured multiple physical paths for all of them.

- **Considerations and Possible Changes.**
  - Are you connecting this host to multiple storage arrays?
  - Do you want to configure multiple physical paths for all of those arrays?
  - If not, you need to list the arrays for which you have not configured multiple physical paths (that is, the ones for which you do not want to enable multipathing) in this section.
 Values

- You can list arrays by WWID, device name, and device type.
  - `wwid` blacklists individual devices using their World Wide Identifier (WWID)
  - `devnode` identifies specific devices to blacklist
  - `device` blacklists all devices from a specific vendor or model

- For examples and specific information, see documentation for the Device-Mapper Multipath specification, such as the Red Hat guide, *Using Device-Mapper Multipath: Configuration and Administration*.

blacklist_exceptions

```sh
## By default, devices with vendor = "IBM" and product = "S/390.*" are
## blacklisted. To enable multipathing on these devices, uncomment the
## following lines.
#blacklist_exceptions {
#    device {
##        vendor"IBM"
#        product "S/390.*"
#    }
#}
```

 Description

This section is for use when you exclude arrays from multipathing by listing them in the blacklist section and there is a subset of those arrays for which you want to enable multiple physical paths.

 Considerations and Possible Changes

List any storage devices (by WWID, device, or devnode) for which you a) want to enable multipathing and b) you have excluded in the blacklist section.

 Values

Exceptions must be specified in the same way as the original items in the blacklist were specified. For example, if you specified the array using a WWID in the blacklist section, you must specify the exceptions using WWID.

 Example

If you have some storage arrays connected to XenServer from the same vendor and you want to enable multipathing for some, but not all, you could list the storage array model in
the blacklist section and then specify the models you want to configure multipathing for in
the blacklist exceptions section.

This section might be used if the XenServer hosts in your pool connect to several different
storage arrays from the same vendor but you did not configure multiple physical paths for all
of them. In this situation, you would list the devices that do not have multiple paths in the
blacklist section and then list the arrays with multiple paths in the blacklist_exceptions
section.

Note: For an item listed in the blacklist_exceptions section to be re-included, you must
use the same method of listing the device as you did in the black. For example, a devnode
exception does not apply to devices entered using a devnode blacklist entry. This is the case
even if the blacklisted device is associated with that devnode.

defaults

```bash
## Use user friendly names, instead of using WWIDs as names.
defaults {
    user_friendly_names no
}
```

- **Description**

This section provides a variety of settings that control how paths are handled, load balancing
algorithms, and other settings XenServer requires to communicate with your array over
multiple paths.

In the standard Linux implementation of multipath.conf, the defaults section includes a
series of commented out values. Users can comment these values back in to the file. Citrix
customizes the defaults section so it includes commonly used values. Consequently, the
multipath.conf file on XenServer hosts does not include all available values for this section.

- **Considerations and Possible Changes**

Compare the settings in this section against the settings your vendor recommends. If
necessary, modify this section so it matches the settings your vendor recommends.

Note: Vendors may have two sets of settings for arrays that vary according to whether or
not you are enabling Asymmetric Logical Unit Access (ALUA).

You can find information about each specific setting by searching the web for information
about multipaths device configuration attributes.

multipaths

- **Description**: Citrix does not list the multipaths section in the XenServer multipath.conf file.
  For more information about this section, search the web for information about multipaths
device configuration attributes.

devices

```yaml
## some vendor specific modifications
devices {
  device {
    vendor "DELL"
    product "MD3000i"
    path_grouping_policy group_by_prio
    getuid_callout "/sbin/scsi_id -g -u -s /block/%n"
    path_checker rdac
    prio_callout "/sbin/mpath_prio_rdac /dev/%n"
    hardware_handler "1 rdac"
    failback immediate
  }
}
```

- **Description:** Citrix lists many of the storage arrays on the *XenServer Hardware Compatibility List* in the devices section. The following settings noteworthy; however, not all settings are used for all arrays:

  - **user_friendly_names.** Enables a system to use alias names to the multipath. By default, XenServer is not set to support user_friendly_names. Do not enable user friendly names unless Citrix or your storage vendor instructed you to do so.

  - **path_grouping_policy.** Indicates what path grouping policy XenServer applies to unspecified multipaths. The path grouping policy varies by array model. Possible values include:

    - **group_by_prio** = 1 priority group for each path priority value
    - **multibus** = all valid paths in 1 priority group
    - **failover** = 1 path per priority group
    - **group_by_serial** = 1 priority group for each detected serial number
    - **group_by_node_name** = 1 priority group for each target node name

  - **path_checker.** Indicates the method XenServer should use to determine the path state.

  - **path_selector.** Indicates the default algorithm XenServer should use to select the path for the next I/O operation. Possible values include `round-robin` amongst others.

  - **hardware_handler.** Indicates a module for XenServer to use when performing certain actions when changing path groups or handling I/O errors. For example, `alua` may be specified as the **hardware_handler** for ALUA-compliant arrays.

  - **failback.** This setting indicates how XenServer should handle failback. It can be expressed as a numeric value, set to `manual`, or set to `immediate` (default). When this value is set to manual, failback only occurs when an administrator performs it manually.
no_path_retry. Indicates the number of times the system should try to use a failed path.

rr_min_io. Indicates the number of I/O requests XenServer routes to a path before changing to the next path in the current path group. By default, the value is 1000.

prio_callout. Indicates which arguments to use to get a path priority value. When this setting is not specified, all paths are treated as equal.

prio. Indicates the function XenServer should call to get a path priority value. Some possible values include emc, alua, ontap, and rdac amongst others.

polling_interval. Defines in seconds how long XenServer should wait between two path checks. The default value is 5.

Note: In general, provided the settings in this section match those your vendor provides, Citrix only recommends modifying individual device settings for advanced users or upon recommendation of Citrix Technical Support or your storage vendor’s technical support.

Considerations and Possible Changes

Compare the settings in this section against the settings your vendor recommends. If necessary, modify this section so it matches the settings your vendor recommends.

Note: Vendors may have two sets of settings for arrays that vary according to whether or not you are enabling Asymmetric Logical Unit Access (ALUA).

You can find information about each specific setting by searching the web for information about multipaths device configuration attributes.

Multipath Handler Support: DM-MP, MPP RDAC, and DMP RDAC

XenServer supports two different multipath handlers: Device Mapper Multipathing (DM-Multipath or DM-MP) and Multipathing Proxy Redundant Disk Array Controller (MPP RDAC). It also indirectly supports DMP RDAC. The multipathing handler you need to use depends on your array model.

Background

By default, XenServer uses Linux native multipathing (DM-MP), the generic Linux multipathing solution, as its default multipathing handler. However, XenServer supplements this handler with additional features so that XenServer can recognize vendor-specific features of storage devices.

Since it is the XenServer default, DM-MP is the only multipathing handler available in XenCenter. If you enable the multipathing checkbox in XenCenter, XenServer expects the array you are using requires DM-MP. Typical examples of DM-MP arrays with portal mode include many NetApp and HP arrays.
For LSI and LSI-based arrays, XenServer also supports LSI Multi-Path Proxy Driver (MPP) for the Redundant Disk Array Controller (RDAC). Unlike arrays that require DM-MP handler, you cannot enable multipathing through XenCenter for arrays that require MPP RDAC. You must enable MPP RDAC support using a CLI command. Typical examples of MPP RDAC arrays include Dell MD3000-series arrays, IBM DS4000-series arrays, and others mentioned in CTX122824.

**Selecting a Multipathing Handler**

Citrix recommends users consult their array-vendor documentation or best-practice guide to determine precisely which multipath handler to select.

In general, most recent arrays are only supported with DM-MP. However, some older arrays are only supported with MPP RDAC. LSI array data paths typically work best with the MPP RDAC drivers.

In some cases, selecting a multipathing handler requires trial and error. In other cases, it is simple and you can just use the default handler. Before you enable multipathing, review the table that follows to get a general indication of the handler to use:

<table>
<thead>
<tr>
<th>Array Series</th>
<th>Handler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell MD 3000 series</td>
<td>MPP (default)</td>
</tr>
<tr>
<td>Fujitsu Eternus Storage</td>
<td>MPP RDAC</td>
</tr>
<tr>
<td>HP StorageWorks Modular Smart Array (MSA)</td>
<td>DMP (default)</td>
</tr>
<tr>
<td>HP StorageWorks Enterprise Virtual Array (EVA)</td>
<td>DMP (default)</td>
</tr>
<tr>
<td>IBM DS series</td>
<td>MPP (default)</td>
</tr>
<tr>
<td>IBM SANs</td>
<td>DMP RDAC</td>
</tr>
<tr>
<td>LSI, LSI-based arrays</td>
<td>MPP RDAC</td>
</tr>
<tr>
<td>NetApp</td>
<td>DMP (default)</td>
</tr>
<tr>
<td>Sun ZFS</td>
<td>MPP RDAC</td>
</tr>
</tbody>
</table>

This table is only intended to provide a starting point and is not meant to be definitive.

**Note:** This table lists examples of storage believed to require a specific multipathing handler to help you realize when you may need to use the MPP RDAC handler. The XenServer Hardware Compatibility List changes periodically and this table is not meant to imply these arrays are on the XenServer Hardware Compatibility List. Always check to XenServer Hardware Compatibility List before purchasing hardware for use with XenServer.
Begin by attempting to configure multipathing using the handler typically associated with the array. If you see following problems, you may need to switch to MPP RDAC or that you run DMP and MPP simultaneously:

- XenCenter shows 1 path of 1 path is active. Likewise, “multipath –ll” shows you also one 1 path only.

- “multipath –ll” does not show the type and product names of the SAN, but it will show MD VIRTUAL DEVICE

- “ll /sys/clas/scsi_device/” will show one more device together with all multiple dmp multiple path devices. The disk is attached to this device, and that is the reason why you can see only 1 path over 1 path.

If, after configuring DM-MP multipathing, you discover you need to use MPP RDAC, you can enable it without disabling DM-MP.

**Enabling Multipathing**

After performing the physical configuration, the general process you use to enable multipathing varies according to whether or not your array requires the MPP RDAC handler:

- If you are enabling DM-MP multipathing, you can do so from XenCenter as described in “To enable multipathing in XenCenter”

- If you are enabling MPP RDAC, enable multipathing in XenCenter (that is, select the Enable multipathing on this server check box in the Multipathing tab on the host’s Properties dialog) and see page 47.

**Important**: Citrix recommends either (a) enabling multipathing in XenCenter **before** you connect the pool to the storage device or (b) if you already created the storage repository, putting the host into Maintenance Mode before you enable multipathing.

**To enable multipathing in XenCenter (enables DM-MP)**

1. After editing the multipath.conf file on all hosts in the pool, open XenCenter, select the host and then the **General** tab.

2. Click the **Properties** button and then click on the **Multipathing** tab.

3. Select the **Enable multipathing on this server** check box, and click OK.

4. Repeat this process for all hosts in the pool.

   If multipathing is enabled correctly, you should see all of the paths marked as active in the Multipathing section on the **General** tab for the SR.
**Note:** To enable multipathing using the CLI, see the *XenServer Administrator’s Guide.*

*Enabling MPP RDAC Handler Support for LSI Arrays*

To enable support for the MPP RDAC handler perform the following procedure on each host in the pool.

**To enable the MPP RDAC handler**

1. Open a console on the host, and run the following command:

   ```bash
   # /opt/xensource/libexec/mpp-rdac --enable
   ```

2. Reboot the host.
Chapter 6: Creating the Storage Repository

This chapter explains how to create a storage repository after enabling iSCSI multipathing, including:

- How to select the most appropriate options in XenCenter based on the number of Target IQNs your array returns
- How to interpret the IQN as XenCenter displays it
- How to use the wildcard masking option in XenCenter

Understanding Target IQNs for iSCSI Multipathing

When using XenCenter to create a storage repository for hosts with multiple paths, be sure to select the correct option—an IQN or Wildcard Masking (*)—for the number of target IQNs your array returns.

When you create a storage repository for either iSCSI software initiator or iSCSI HBA, XenServer requires that you provide it with the target IQN, which is the address used to identify the iSCSI storage device. However, when you query the storage device for its IQN, it may return one or more IQNs, depending on the specific device.

After multipathing is enabled, all paths should see the same LUN. When XenServer queries the target, the target may return one or more IQNs.
For storage devices that return multiple IQNs, when you are creating the storage, you must select the Wildcard Masking (*) option in XenCenter, which is denoted by an asterisk in front of the value returned in the **Target IQN** list box. The wildcard masking option appears as follows:

![Image of XenCenter Storage Repository wizard](image)

Asterisk indicates wildcard option

*This screen capture shows the XenCenter Storage Repository wizard’s Wildcard Masking (*) option, which appears after pressing Discover IQNs. The Wildcard Masking (*) option is used for arrays that return multiple IQNs associated with one or more IP addresses. In this example, which is for a Dell Compellent array, the user entered one IP address. The array returned different IQNs — all associated with that one IP address.*

The illustration that follows compares three arrays: an array that returns one IQN associated with multiple addresses, an array that returns multiple IQNs associated with one IP address, and an array that returns multiple IQNs associated with multiple IP addresses.
This illustration shows how some iSCSI storage devices (targets) return only one IQN whereas other iSCSI storage devices return multiple IQNs when XenServer queries the target storage device for the IQN.

In the top panel in the previous illustration, XenServer queries a NetApp storage target. In this example, the user enters all of the IP addresses associated with the target in the **Target Host** box. After clicking **Discover IQN**, the array returns only one IQN that is associated with each IP
address. In this case, selecting any of the returned IQN/IP values (not wildcard) will create multiple paths to the target.

In the middle panel of the previous illustration, XenServer queries a Dell Compellent storage target. In this example, the user enters the one IP address associated with the target in the Target Host box. After clicking Discover IQN, the array returns multiple IQNs associated with one IP address. In this case, the user must select the wildcard (*) option so XenServer can create multiple paths to the target.

In the bottom panel of the previous illustration, XenServer queries a DataCore storage target. In this example, the user enters all IP addresses associated with the target in the Target Host box. After clicking Discover IQN, the array returns multiple IQNs associated with multiple IP addresses. In this case, the user must select the wildcard (*) option so XenServer can create multiple paths to the target.

The arrays used in the illustration are meant as examples and are not the only arrays that apply to the shown scenarios.

**Important:** Do not use the XenCenter (*) wildcard option if it is not necessary for your array (based on the guidelines about returned values in this section). Using the (*) wildcard option when it is not appropriate can actually slow down your storage performance.

**Understanding Returned Values**

The value returned as the Target IQN displayed in XenCenter also includes the IP address of the NIC on the controller and the port number the host and array use for communication.

The following illustration of a sample IQN value XenCenter might display:

![IQN Illustration](image)

*This illustration shows a sample IQN number, as it might be displayed in XenCenter. The first part of the IQN is vendor specific and does not change. It includes the date the storage vendor applied for the IQN number and the storage vendor name. The second part of the IQN number includes vendor specific information. This is the part of the IQN to examine when determining whether or not to select the Wild Masking (*) option in the XenCenter Storage Repository wizard.*
To create an iSCSI storage repository after enabling multipathing

1. If you have not done so already, enable multipathing.

2. In XenCenter, right-click the pool, and click New SR.

3. On the Type page, select Software iSCSI.

4. On the Name page, enter a meaningful name, and click Next.

5. On the Location page, do the following:

   a) On the Target Host box, enter the IP address of the storage controller containing the LUN, as follows:

      i. One IP address. If there is only one IP address associated with the storage target, enter that IP address. An example of an array for which you only enter one IP address is the Dell Compellent. Likewise, you only enter one IP address for most NetApp arrays.

      ii. Multiple IP addresses. If there are multiple IP addresses associated with the storage target, enter all of those IP address separated by commas. Potential examples of arrays for which you need to enter all IP addresses include DataCore and StarWind.

         Tip: As a general guideline, if in doubt, start by entering one IP address in the Target Host box. If all of the expected IQNs do not appear when you click Discover IQNs, add the other IP addresses as well.

   b) If you are using CHAP Authentication, select Use CHAP and enter the CHAP user and secret.

      If you enable CHAP, it is recommended to have the same CHAP username/password for initiators in the same initiator group (as is the case with a pool of XenServer hosts connecting to the same initiator group).

   c) Click the Discover IQNs box to discover the IQNs on the device.

<table>
<thead>
<tr>
<th>If XenCenter returns…</th>
<th>Then in the Target IQN list box…</th>
</tr>
</thead>
<tbody>
<tr>
<td>only one identical IQN value</td>
<td>select the IQN associated with the storage device (target) that corresponds with the LUN you want to configure.</td>
</tr>
<tr>
<td>multiple distinct IQNs associated with one IP address</td>
<td>select the * option from the Target IQN list box</td>
</tr>
<tr>
<td>multiple distinct IQNs associated with one multiple IP address</td>
<td>select the * option from the Target IQN list box</td>
</tr>
</tbody>
</table>
The number of IQNs that XenServer returns (when multipathing is configured correctly) depends on your:

- Storage configuration (for example, how many NICs on the controller, how many controllers, the failover mechanism, other software configurations, and so on)

- Storage vendor’s IQN/IP scheme

d) Click the **Discover LUNs** box. Select the LUN to which you want XenServer to connect.

e) Click **Finish** to finish creating the storage repository and exit the wizard.
Chapter 7: After Enabling Multipathing

This chapter provides information about a variety of topics, including:

- Verifying Multipathing is Working
- Increasing the Time Outs on Virtual Machines

Verifying Multipathing is Working Correctly

Checking that multipathing is working correctly is an important step in the multipathing process. Common signs multipathing is not working include: alerts in XenCenter, the inability of traffic to failover, or only part of the paths being active.

After you configure multipathing, consider verifying not only that both paths are active but also that the data sent and received on both paths is balanced. If multipathing is configured incorrectly, it is possible, in some cases, for both paths to be active but have less than optimal throughput or even have one path that barely works (but is still marked active).

To verify multipathing is working you can either do a cable push/pull test or block and unblock switch ports (from the host side as well as the target side).

To verify multipathing is working (cable push/pull test)

⚠️ Do not perform this procedure in a production environment. After an array is in production, this procedure may cause an outage.

1. Unplug one of the cables from storage port on the host.
Assuming your environment originally had 4 paths to the storage, if XenCenter says 2 of 4 paths are active, multipathing is working correctly.

2. Check the storage traffic failed over by running the following command:

   `lun stats -o -i<checking interval><path to LUN>`

   Check to make sure the traffic has resumed on the storage port that is still active.

*To check if XenServer is using both paths*

1. Using a utility like Putty, connect to the storage array.

2. In the CLI window, enter the following command to generate traffic:

   `lun stats -o`

3. Examine the results. You should see approximately the same amount of traffic on both paths.

   **Tip:** To reset these counters, run the `lun stats --z` command.

*To display stats on each path to a LUN or volume*

1. From the XenServer host, in the **Console** tab, run the following to display I/O stats for a VM:

   `vmstat`

2. From the XenServer host, in the **Console** tab, run the following:

   `iostat`

**Additional Tasks**

*Increasing the Time Outs on Virtual Machines*

To increase the Disk timeout on a Windows machine to avoid disk I/O timeouts happening on Virtual machine during controller faults, at a Windows virtual machine

1. Set the Windows timeout value to 190 (Sec) by modifying the registry in the virtual machine as follows:

   Start->run->regedit->HKLM->System->CurrentControlSet->Services->disk->TimeOutValue=190
Appendix A: Troubleshooting

This appendix provides information about the following:

- Guidance for using multipathing CLI commands
- How to display the paths in use
- Prio errors in the syslog

Using Multipathing CLI Commands

Multipath support in XenServer is based on the device-mapper multipathd components. Consequently, the XenServer Storage Manager API activates and deactivates multipath nodes.

Unlike the standard `dm-multipath` tools in Linux, device mapper nodes are not automatically created for all LUNs on the system. It is only when the storage management layer actively uses LUNs that the new device mapper nodes are provisioned.

Therefore, it is unnecessary to use any of the `dm-multipath` CLI tools to query or refresh DM table nodes in XenServer. If you need to query the status of device-mapper tables manually or list active device mapper multipath nodes on the system, use the `mpathutil` utility:

- `mpathutil list`
- `mpathutil status`

**Note:** Due to incompatibilities with the integrated multipath management architecture, the standard `dm-multipath` CLI utility should not be used with XenServer. Use the `mpathutil` CLI tool for querying the status of nodes on the host.
Displaying Paths in Use

1. Run the command `multipath -ll` to view the current multipath topology as presented by control domain.

Increasing the Number of Errors Captured in the System Log for Multipathing

When troubleshooting multipathing issues, setting the multipathing verbosity to the maximum in the multipath.conf file increase the number of prio errors that are captured in the syslog, which can make it easier to see errors.

To increase the verbosity for multipathing

1. Using a program like WinSCP or the CLI method of your choice, on each host in the pool, open the `/etc/multipath.conf` file.

2. Find the section for your storage device, in the `defaults` section, add the keyword “verbosity” and increase the verbosity to the maximum (6):

   ```
   defaults
   {
   user_friendly_names no
   pg_prio_calc “avg”
   verbosity 6
   }
   ```

   **Note**: Valid values for the verbosity keyword are 0 to 6, where 6 is the maximum verbosity. By default, without specifying a keyword, verbosity is set to 2.

3. Save the multipath.conf file and close it. Prio errors will begin to appear in the syslog.

MPP RDAC Testing and Troubleshooting Commands

If you use MPP RDAC as the multipathing handler, use the following commands to display RDAC driver internal information for a virtual target:

1. Run the following commands to display internal information from RDAC for a virtual target.

   ```
   mppUtil -g #
   ```

   where # is your target number from 0 to maximum number of array modules (mppUtil -m).

   ```
   mppUtil -g 0
   ```
2. Verify how many LUNs are detected and being multipathed in for the visible LUN in the Control Domain (Dom0) by running:

```
# ARRAY=`/opt/xensource/bin/xe-getarrayidentifier <DEVICE>`
/usr/sbin/mppUtil -g ${ARRAY} | grep hostId
```

In this example, `<DEVICE>` represents the visible LUN. If your LUN has the device ID of `/dev/sdb`, enter `/dev/sdb` instead of the `<DEVICE>` placeholder.
Appendix B: Asymmetric Logical Unit Access (ALUA)

This appendix provides general information about how to configure XenServer 6.0 and higher for use with arrays that require the Asymmetric Logical Unit Access (ALUA) standard. Some arrays may require ALUA when there are multiple controllers configured as high availability pair, so that one controller fails over to the other. This section includes information about the following:

- A very brief explanation of ALUA
- A very brief overview of general requirements
- A summary of tasks
- How to add ALUA settings to multipath.conf

This section is only intended to get you started with ALUA.

Overview

Having multiple controllers on a storage array provides both throughput and redundancy. However, for some arrays, you must enable ALUA and use ALUA settings in the multipath.conf file. If you do not, it can introduce inefficient paths between the XenServer host and the storage or simply not work.

ALUA is a SCSI standard some arrays use to ensure that storage traffic takes the most efficient path from the host to the storage. If ALUA is not enabled correctly on both the storage controller and XenServer host, storage traffic may experience latency.

ALUA is not used on all brands of storage. However, some vendors, such as NetApp and EMC, use the ALUA standard to ensure storage traffic takes the most efficient path when users configure a second storage controller for failover. In a failover configuration, the second controller, known as
the partner controller, can access the LUN if the primary controller (owner) associated with the LUN fails.

The ALUA standard is used on arrays such as the EMC VMAX, the EMC VNX, (Unified Storage), and NetApp FAS arrays.

**Note:** For examples of how to configure ALUA for use with XenServer, see:

- CTX132976— *ALUA Multipathing on XenServer 6.0 for Enterprise Arrays*

### General Requirements

#### Fibre Channel

The recommended requirements for Fibre Channel SAN configurations for multipathing are:

- Two or more storage controllers on the array
- At least two HBA ports per host
- One (or typically two) Fibre Channel SAN switches
- A single SAN fabric zone per path

#### iSCSI

The recommended requirements for iSCSI SAN configurations for multipathing are:

- Two or more storage controllers on the array
- At least two NICs or iSCSI HBA ports per host
- At least two network switches dedicated to storage traffic

**Note:** For all SAN configurations (boot from SAN and non-boot from SAN), the best practice is not to have any present data LUNs from the SAN to the XenServer host during the installation process.

### General Task Overview

The specific steps you need to perform vary by array. At a high level, configuring ALUA requires the following tasks:

1. Setting up the physical equipment.
2. Configuring a pair of High Availability controllers.
3. Retrieving the WWPNs or IQNs from the storage ports on the XenServer host.
4. Performing the required networking configuration:
   a. (For Fibre Channel.) Configuring zoning on the switch.
   b. (For iSCSI.) Configuring subnets.

5. Configuring the storage, including tasks like creating initiator groups (if applicable), creating
   LUNs, and enabling any required vendor-specific settings.

6. Configure storage on each XenServer host in the pool, including as applicable:
   a. Configuring at least two Fibre Channel ports as targets (for Fibre Channel).
   b. Editing the multipath.conf file.
   c. Enabling multipathing in XenCenter (or using the CLI, if desired).
   d. Creating the SR. (If you select the pool node in XenCenter when you create the SR,
      you only need to create the SR once.)

**Adding ALUA Settings to the multipath.conf File**

For ALUA to work, you must replace the settings specified for your device in the multipath.conf file
on each XenServer host with the settings in, if available, the Citrix documentation for configuring
ALUA for your specific array or the settings specified by your vendor. Perform these steps on each
XenServer host before enabling multipathing.

**To add ALUA settings to the multipath.conf file**

1. Using either WinSCP or an editor like VI in the XenServer console, edit the multipath.conf
   file. For example, to use VI, run the following at the XenServer command prompt:
   
   VI /etc/multipath.conf

2. Scroll down to the devices section of multipath.conf, find your storage device if listed, if not
   add it.

3. In either case, be sure to specify the ALUA settings for your vendor. If your device is already
   listed, replace the text for the device with the ALUA settings.

4. Restart the hosts and then verify the ALUA configuration by running the following
   command:
   
   # multipath -ll

This should list all known array controllers on the host. One or more entries indicate that multi-path
is in operation.
This appendix provides additional sources of information, including:

- General XenServer multipathing references
- Other third-party sources of multipathing information
- A list of vendor-specific storage information authored by Citrix
- Articles to help you troubleshooting multipathing

**General XenServer Multipathing References**

You may be interested in the following additional Citrix multipathing resources:

- CTX118791—*Multipathing Overview for XenServer 5.0*
- CTX121364—*Multipath Implementations in XenServer*, which is about when to use DMP and MPP RDAC
- CTX132976—*ALUA Multipathing on XenServer 6.0 for Enterprise Arrays*
- *XenServer Administrator’s Guide*
- CTX121231—*How to Configuration a Redundant Disk Array Controller on XenServer 5.0*
Other Multipathing References

XenServer uses a standard Linux CentOS multipathing stack.

- Additional insight into Linux multipathing can be found by searching the Internet for article and documentation about Linux multipathing. For example, at the time this guide was written, a description of the multipath.conf file is available in “The DM-Multipath Configuration File” chapter of the Red Hat Enterprise Linux 6 DM Multipath: DM Multipath Configuration and Administration guide on the Red Hat website.

- Information about parameters in the multipath.conf file can be found by searching the Internet (for example, using a parameter as a keyword may bring up information about the settings in the file overall).

Vendor-specific Multipathing Documentation

Vendors typically publish interoperability guides. If you are having trouble with your multipathing configuration, it may be helpful to check these guides for your vendor’s latest multipathing settings and comparing them against those in the multipath.conf file in case they changed since XenServer was released. Citrix also provides some vendor-specific storage documentation, including:

- CTX133921 — Citrix XenServer and NetApp Storage Best Practices
- CTX126121 — Citrix XenServer and EMC CLARiiON CX4 Series Configuration Guide
- CTX126972 — How to Enable Multipathing on Dell Powervault MD3200i
- CTX127055 — How to Configure XenServer Multipathing for Dell MD3200 Storage Area Network
- CTX120963 — Multi-pathing on the HP MSA2012SA SAS-attached Storage Area Network

Even though the specific actions in the UI procedures in some of these guides and articles may be out dated, in many cases the multipathing and best practices still apply.

Resources for Troubleshooting Multipathing

- CTX118791 — Multipathing Overview for XenServer 5.0. This includes general troubleshooting commands for multipathing, some of which are included in this document, and other information.
- CTX124067 — How to Rebuild Initrd for MPP Support
- CTX125888 — How to Reactivate an Inactive Multipath
## Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Comments</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Initial Release</td>
<td>January 21, 2013</td>
</tr>
</tbody>
</table>
About Citrix

Citrix Systems, Inc. (NASDAQ:CTXS) is the leading provider of virtualization, networking and software as a service technologies for more than 230,000 organizations worldwide. Its Citrix Delivery Center, Citrix Cloud Center (C3) and Citrix Online Services product families radically simplify computing for millions of users, delivering applications as an on-demand service to any user, in any location on any device. Citrix customers include the world’s largest Internet companies, 99 percent of Fortune Global 500 enterprises, and hundreds of thousands of small businesses and prosumers worldwide. Citrix partners with over 10,000 companies worldwide in more than 100 countries. Founded in 1989, annual revenue in 2010 was $1.87 billion.

©2013 Citrix Systems, Inc. All rights reserved. Citrix®, Access Gateway™, Branch Repeater™, Citrix Repeater™, HDX™, XenServer™, XenCenter™, XenApp™, XenDesktop™ and Citrix Delivery Center™ are trademarks of Citrix Systems, Inc. and/or one or more of its subsidiaries, and may be registered in the United States Patent and Trademark Office and in other countries. All other trademarks and registered trademarks are property of their respective owners.