Live Migration of Virtual Machines across data centers with HPE 3PAR Cluster Extension & Microsoft Hyper-V
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Executive summary

Server virtualization, also known as hardware virtualization, is a hot topic in the information technology (IT) world because of the potential for serious economic benefits. Server virtualization enables multiple operating systems to run on a single physical machine as virtual machines (VMs). With server virtualization, you can consolidate workloads across multiple underutilized server machines onto a smaller number of machines. Fewer physical machines can lead to reduced costs through lower hardware, energy, and management overhead, plus the creation of a more dynamic IT infrastructure.

Windows Hyper-V, the next-generation Hyper-Visor-based server virtualization technology, is available as an integral feature of Windows Server 2008 R2/2012/2012 R2 and enables you to implement server virtualization with ease. One of the key use cases of Hyper-V is to achieve Business Continuity and disaster recovery through complete integration with Microsoft® Failover Cluster. The natural extension of this ability is to complement this feature with the HPE products like HPE 3PAR Cluster Extension and HPE 3PAR Remote Copy to achieve comprehensive and robust multi-site disaster recovery and high availability solution. This also allows you to utilize Windows Hyper-V in combination with HPE 3PAR Cluster Extension to migrate VMs live across data centers, between servers and storage systems, without affecting user access significantly.

This white paper briefly touches upon the Windows Hyper-V and HPE 3PAR Cluster Extension (CLX) features, such as Live Migration and quick migration, functionality, best practices, and various use cases. This paper concludes with the step-by-step details for creating a CLX solution in Hyper-V environment for the live migration feature. There are many references also provided for referring to relevant technical details.

Applicability and definitions

This document is applicable for implementing HPE 3PAR Cluster Extension Software on Microsoft Hyper-V™ platform. The following table lists the acronyms used in this document and their definitions:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>HPE 3PAR CLX (CLX)</td>
<td>HPE Cluster Extension Software for HPE 3PAR StoreServ Storage Array</td>
</tr>
<tr>
<td>MSFC</td>
<td>Microsoft Failover Cluster</td>
</tr>
<tr>
<td>MSFC Quorum Models supported by CLX</td>
<td>Node Majority, Node and File Share Majority (FSW)</td>
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<td>Hyper-V</td>
<td>Server Virtualization technology from Microsoft</td>
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<tr>
<td>Host OS</td>
<td>The physical server on which Hyper-V is installed</td>
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<td>VFC</td>
<td>Hyper-V Virtual Fibre Channel routes physical volume from storage array to Guest OS</td>
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<td>Pass through disk</td>
<td>Pass through disk routes a physical volume from the Host OS to Guest OS</td>
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<td>RC Group</td>
<td>3PAR Remote Copy Group</td>
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Target audience

This document is for anyone who plans to implement HPE 3PAR Cluster Extension on a multi-site or stretched cluster with HPE 3PAR array based Remote Copy solution in a Hyper-V environment. The document describes Hyper-V configuration on HPE ProLiant servers, explains how to create a virtual machine, details method of adding a virtual machine to a Failover Cluster, and finally mentions the CLX supported scenario with an example. For further information on Cluster Extension, see the documentation available on the Cluster Extension website (http://h18006.www1.HPE.com/storage/software/ces/index.html?jumpid=reg_r1002_usen) using the Technical documentation link under Support.

Introduction to HPE 3PAR StoreServ Cluster Extension (CLX)

HPE 3PAR StoreServ Cluster Extension offers protection against application downtime due to a fault, failure, or site disaster by extending a local cluster between data centers over metropolitan distance. HPE 3PAR StoreServ Cluster Extension reinstates critical applications at a remote site within minutes of an adverse event, integrating your open-system clustering software and HPE 3PAR Remote Copy to automate failover and failback between sites. This dual integration enables the cluster software to verify the status of the storage and the server cluster. The cluster software can then make correct failover and failback decisions, thus minimizing downtime and accelerating recovery.

CLX provides efficiency that preserves operations and delivers investment protection. CLX automates the time-consuming, labor-intensive processes required to verify the status of the storage and the server cluster, thus allowing the correct failover and failback decisions to be made to reduce downtime. CLX offers protection against application downtime from fault, failure, and disasters by extending a local cluster between data centers over large geographical distances.

To summarize, the key features of CLX are as follows:

- **Protection against transaction data loss** – The application cluster is extended over two sites and the storage is replicated at the second site using array-based replication methodology. The data, therefore, exists universally with virtually no difference (depending on the replication method) in the data storage of site A and site B. No Single Point of Failure (SPOF) solution to increase the availability of company and customer data.

- **Fully automatic failover and failback** – Automatic failover and failback reduce the complexity involved in a disaster recovery situation. It is protection against the risk of downtime, whether planned or unplanned.
• **No server reboot during failover** – Disks on the server of both the primary and secondary sites are recognized during the initial system boot in a CLX environment. Therefore, LUN presentation and LUN mapping changes are not necessary during failover or failback for a truly hand-free disaster tolerant solution.

• **No single point of failure** – Identical configuration of established SAN infrastructure redundancies is implemented on site B, providing supreme redundancy.

• **MSFC Node Majority/Node and File Share majority integration** – CLX Windows uses the Microsoft Node Majority / Microsoft Node and File Share Witness (FSW) quorum feature. These quorum models provide protection against split-brain situations without the single point of failure of a traditional Quorum disk. Split-brain syndrome occurs when the servers at one site of the stretched cluster lose all connection with the servers at the other site and the servers at each site form independent clusters. The serious consequence of the split-brain is corruption of business data, because data is no longer consistent.

• **HPE 3PAR StoreServ Storage arrays support** – The entire range of 3PAR arrays is supported. Refer the SPOCK website for details.

• **Support for Live/Quick Migration** – CLX supports Live/Quick migration of Highly Available VMs between nodes with in or across datacenters.

One of the Quick Migration use cases of CLX is described in the figure 2 and 3. Before planned migration applications or VMs are hosted on the primary site and the business critical data is replicated to the recovery site for disaster recovery.

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**Figure 2: Before planned migration**
• During the planned migration CLX automates the application or VM storage failover and change in replication direction in conjunction with Microsoft Clustering solution achieving Business Continuity and High Availability.

**Figure 3: After planned migration**

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**Server virtualization**

In the computing realm, the term virtualization refers to presenting a single physical resource as many individual logical resources (like platform virtualization), and making many physical resources appear to function as a singular logical unit (like resource virtualization). A virtualized environment may include servers and storage units, network connectivity and appliances, virtualization software, management software, and user applications. A virtual server, or VM, is an instance of some operating system platform running on any given configuration of server hardware, centrally managed by a Virtual Machine Manager, or hypervisor, and consolidated management tools.
Benefits of virtualization

Virtualized infrastructure can benefit companies and organizations of all sizes. Virtualization greatly simplifies a physical IT infrastructure to provide greater centralized management over your technology assets and better flexibility over the allocation of your computing resources. This enables your business to focus resources when and where they are needed most, without the limitations imposed by the traditional "one computer per box" model.

Virtualization enables you to create VMs that share hardware resources and transparently function as individual entities on the network. Consolidating servers as VMs on a small number of physical computers can save money on hardware costs and make centralized server management easier. Server virtualization also makes backup and disaster recovery simpler and faster, providing for a high level of business continuity. Virtual environments are also ideal for testing new operating systems, service packs, applications, and configurations before rolling them out on a production network.

Introduction to Hyper-V

Windows Hyper-V, the next-generation Hyper-visor-based server virtualization technology, is available as an integral feature of Windows Server 2008 R2/2012/2012 R2 and enables you to implement server virtualization with ease. Hyper-V allows you to make the best use of your server hardware investments by consolidating multiple server roles as separate virtual machines (VMs) running on a single physical machine. With Hyper-V, you can also efficiently run multiple different operating systems—Windows, Linux, and others—in parallel, on a single server, and fully leverage the power of x64 computing.

Hyper-V offers great advantage in certain scenarios, such as Server Consolidation, Business Continuity, and Disaster Recovery through complete integration with Microsoft Failover Cluster, Testing and deployment through its inherent ease and scaling capability, and so on. For more details on Hyper-V technology, refer to Microsoft page at https://mva.microsoft.com/en-us/training-courses/introduction-to-hyper-v-jump-start-12644

Introduction to Hyper-V live migration

Hyper-V Live Migration is integrated with Windows Server 2008 R2 /2012 / 2012 R2. Using the feature allows you to move running VMs from one Hyper-V physical host to another without any disruption of service or perceived downtime. Moving running VMs without downtime provides better agility in a data center in terms of performance, scaling, and efficient consolidation without affecting users. It also reduces cost and increases productivity.

Windows Hyper-V also offers a feature called Quick Migration. Live migration and Quick Migration both move running VMs from one Hyper-V physical computer to another. The difference is Quick Migration saves, moves, and restores VMs, which results in some downtime. The Live Migration process uses a different mechanism for moving the running VM to the new physical computer. The various Live Migration steps are summarized as follows:
1. When Live Migration operation is initiated, all VM memory pages are transferred from the source Hyper-V physical computer to the destination Hyper-V physical computer. The VM is pre-staged at the destination Hyper-V physical computer.

2. Clients continue to access the original VM, which results in memory being modified. Hyper-V tracks changed data and recopies incremental changes to the destination Hyper-V physical computer. Subsequent passes get faster as the data set is smaller.

3. When the data set is small, Hyper-V pauses the VM and suspends operations completely at the source Hyper-V physical computer. Hyper-V moves the VM to the destination Hyper-V physical computer and the VM resumes operations at the destination host. This window is very small and happens within the TCP/IP timeout window. Clients accessing the VM perceive the migration as live.

4. The VM is online on the destination Hyper-V physical computer and clients are redirected to the new host.

This makes live migrations of VMs preferable as users have uninterrupted access to the migrating VM. Because a live migration completes in less time than the TCP timeout for the migrating VM, users experience no outage for the migrating VM during steps 3 and 4 of the migration. The TCP timeout is a time window and if the operations are performed within this time window, the reconnection of the client to the VM (and therefore the application hosted within VM) is not necessary. Achieving step 3 and 4 within TCP timeout window is critical for the process of live migration to be successful in the sense of uninterrupted access to the VM.

### Enabling Live Migration across data centers—The CLX value add

The Hyper-V Live Migration process as explained above does not involve any step related to storage, thereby making it mandatory to have shared storage access to all the hosts. This means that VM data is stored on a SAN storage LUN and is provisioned to all physical hosts in the cluster. This solution works perfectly fine in a single data center cluster solution, but how about a solution that is spread across sites?

This is usually the situation in multi-site disaster recovery solutions where a cluster is stretched across sites and each site has a dedicated storage array. The data is made available on both the sites using storage array-based data replication solutions like HPE 3PAR Remote copy software. This is where CLX as a product adds a great value. As explained in the introduction section, CLX seamlessly integrates with Failover Clustering and enables storage-level failovers as part of cluster resource movement across sites. Thereby, it extends High Availability and Business Continuity to the Multi-site Disaster Recovery solution. However, to enable Hyper-V Live Migration across sites CLX had to fulfill additional requirements such as:

1. Develop a mechanism in CLX to be aware of the Hyper-V Live Migration process while continuing to be seamlessly integrated in the Failover Clustering solution.
2. Perform storage failover as part of the VM Live Migration process.
3. Achieve the storage failover related operation within the TCP timeout window without impacting the VM Live Migration process.
4. Manage the storage layer related unfavorable conditions for a VM live migration.

In summary, CLX enables Hyper-V Live Migration across sites, servers, and storage in a completely transparent manner, without any need of learning new products or practices. This feature in CLX and Live Migration enhances the fundamental benefits of Hyper-V live migrations as explained in the section below.

Addition to live migration support, CLX also enables Quick Migration feature of Microsoft failover cluster. For more details see [https://technet.microsoft.com/en-in/library/dd759249.aspx](https://technet.microsoft.com/en-in/library/dd759249.aspx)

### Multi-site Live Migration Benefits

Live Migration-integration of CLX into Microsoft Failover Clustering provides much greater flexibility and agility for your computing environment. It enhances the benefits derived through server virtualization. Some of the key benefits are:

1. Zero downtime maintenance
   The ability to move a VM from one server to other without any downtime takes away one of the biggest headaches from an IT administrator and that is planning a maintenance (downtime) window. With the CLX Live Migration solution updating firmware, HBA, Server, and so on can be performed for a server or servers within a data center without having to worry about user disruption. Now, it is possible to do virtually any maintenance work in and around a data center at regular working hours without impacting end-users.

2. Zero Downtime Load Balancing
   CLX Live Migration can help enhance the performance of a given solution through zero downtime load balancing. A VM can be migrated to another site, server, or storage depending on the resource utilization and availability. For example, a VM can be
migrated to a storage system in the remote data center site depending on IOPS, cache utilization, response time, power consumption, and the like.

3. No Additional Learning Cost
   Using CLX and Hyper-V Live Migration, all the operations such as failover/failback across sites, servers and storage, live migration, quick migration, VM and CLX configurations and so on, can be performed through a well-known management software i.e., Microsoft Failover Cluster GUI. There is no need to learn many different tools/products and their respective features/limitations.

HPE supported configuration/hardware for Windows Server 2008 R2/2012/2012 R2/2016
This section covers the HPE hardware and related components for Windows Hyper-V. As a prerequisite step, it is important to ensure that hardware components are officially supported by HPE. As a best practice it is recommended that support streams must be reviewed for latest information. Support streams list support for various solution components like Server, Storage, FC Switch, Host Bus Adapters (HBA), Network Interface Cards (NIC), and so on. The various available resources are listed in the references section at the end of this document. Alternatively, get in touch with your local HPE account or service representative for definitive information about supported HPE configurations.

Server support

Storage support
For a detailed list of HPE 3PAR StoreServ storage products supported with Windows Hyper-V see [https://h20272.www2.HPEe.com/SPOCK/index.aspx?lang=en&cc=us&HPEappid=117135_SPOCK_PRO_HPE](https://h20272.www2.HPEe.com/SPOCK/index.aspx?lang=en&cc=us&HPEappid=117135_SPOCK_PRO_HPE)


Hyper-V Implementation considerations

Disk performance optimization
Hyper-V offers two different kinds of disk controllers, IDE and SCSI controllers. Both have their distinct advantages and disadvantages. IDE controllers are the preferred choice because they provide the highest level of compatibility for a large range of guest operating systems. However, SCSI controllers can enable a virtual SCSI bus to provide multiple transactions simultaneously. If the workload is disk intensive, consider using only virtual SCSI controllers if the guest OS supports that configuration. If this is not possible, add additional SCSI connected VHDs. It is more effective to select SCSI-connected VHDs that are stored on separate physical spindles or arrays on the host server.

Storage options in Hyper-V

Virtual Hard Disk (VHD) choices
There are three types of VHD files. The following are performance characteristics and tradeoffs of each VHD type:

- **Dynamically expanding VHD**: Space for the VHD is allocated on demand. The blocks in the disk start as zeroed blocks, but are not backed by any actual space in the file. Reads from such blocks return a block of zeros. When a block is first written to, the virtualization stack must allocate space within the VHD file for the block and then update the metadata. This increases the number of necessary disk I/Os for the write and increases CPU usage. Reads and writes to existing blocks incur both disk access and CPU overhead when they access the block mapping in the metadata.

- **Fixed-size VHD**: Space for the VHD is first allocated when the VHD file is created. This type of VHD is less apt to fragment, which reduces the I/O through put when a single I/O is split into multiple I/Os. It has the lowest CPU overhead of the three VHD types because reads and writes do not need to look up the block mapping.

- **Differencing VHD**: The VHD points to a parent VHD file. Any writes to blocks never written to before cause the space to be allocated in the VHD file, as with a dynamically expanding VHD. Reads are serviced from the VHD file if the block is written to. Otherwise, they are serviced from the parent VHD file. In both cases, the metadata is read to determine the mapping of the block. Reads and writes to this VHD can consume more CPU resources and result in more I/Os than a fixed-sized VHD.
• **VHDX**: From Windows Server 2012 onwards, a new format, VHDX, is available along with VHD format. There is a noticeable difference in the storage capacity between the two formats. Further VHDX also provides data corruption protection during power failures and optimizes structural alignments to prevent performance degradation on new, large-sector physical disks.*

  *Source – Above information is referred from following link https://technet.microsoft.com/en-in/library/hh831446.aspx

**Hyper-V Pass through disk**

One of the storage configuration options in Hyper-V child partitions is the ability to use pass through disks. While the former options all have referred to VHD files that are files on the file system of the parent partition, a pass through disk routes a physical volume from the parent to the child partition. The volume must be configured offline on the parent partition for this operation. This simplifies the communication and by design, the pass through disk overhead is lower than the overhead with VHDs.

However, Microsoft has invested in enhancing the fixed-size VHD performance, which has significantly reduced the performance differential. Therefore, the more relevant reason to choose one over the other should be based on the size of the data sets. If there is a need to store large data sets, a pass-through disk is typically the more practical choice. In the virtual machine, the pass through disk is attached either through an IDE controller or through an SCSI controller.

  **Note:**
  
  When presenting a pass through disk, the disk must remain offline on the host OS. This prevents host and guest OS from using the pass through disks simultaneously.

  Pass through disks do not support VHD-related features, like VHD Snapshots, dynamically expanding VHDs, and differencing VHD.

CLX supports pass through disk in Windows server 2008 R2 only.

**Hyper-V Virtual Fibre Channel ***

From Windows Server 2012 onwards, a new feature Hyper-V Virtual Fibre Channel is available, Virtual Fibre Channel for Hyper-V provides the guest operating system with unmediated access to a SAN by using a standard World Wide Name (WWN) associated with a virtual machine. Hyper-V users can now use Fibre Channel SANs to virtualize workloads that require direct access to SAN logical unit numbers (LUNs). Fibre Channel SANs also allow you to operate in new scenarios, such as running the Failover Clustering feature inside the guest operating system of a virtual machine connected to shared Fibre Channel storage.

You need your virtualized workloads to connect easily and reliably to your existing storage arrays. Hyper-V provides Fibre Channel ports within the guest operating system, which allows you to connect to Fibre Channel directly from within virtual machines. This feature protects your investments in Fibre Channel, enables you to virtualize workloads that use direct access to Fibre Channel storage, allows you to cluster guest operating systems over Fibre Channel, and provides an important new storage option for servers hosted in your virtualization infrastructure.

  *Source – Hyper-V Virtual Fibre Channel information is referred from following link: https://technet.microsoft.com/en-in/library/hh831413.aspx

  **Note:**
  
  CLX Supports Hyper-V VFC from Windows Server 2012 onwards.

**Cluster Shared Volumes (CSV)**

With Windows Server 2008 R2/2012/2012 R2, Hyper-V uses CSV storage to simplify and enhance shared storage usage. CSV enables multiple Windows Servers to access SAN storage using a single consistent namespace for all volumes on all hosts. Multiple hosts can access the same Logical Unit Number (LUN) on SAN storage. CSV enables faster live migration and easier storage management for Hyper-V when used in a cluster configuration. Cluster Shared Volumes is available as part of the Windows Failover Clustering feature of Windows Server 2008 R2/2012/2012 R2.

  **Note:**
  
  CLX Supports CSV from Windows Server 2012 onwards.

**Hyper-V integration services**

The integration services provided with Hyper-V are critical to incorporate into the general practices. These drivers improve performance when virtual machines make calls to the hardware. After installing a guest operating system, be sure to install the latest drivers. Integration services target specific areas that enhance the functionality or management of supported guest operating systems. Periodically, check for integration service updates between the major releases of Hyper-V.
Memory usage maximization
In general, allocate as much memory to a virtual machine as you would for the same workload running on a physical machine without wasting physical memory. If you know how much RAM is needed to run a guest OS with all required applications and services, begin with this amount. Be sure to include a small amount of additional memory for virtualization overhead. 64 MB is typically sufficient.
Insufficient memory can create many problems including excessive paging within a guest OS. This issue can be confusing because it might appear to be that the problem is with the disk I/O performance. In many cases, the primary cause is because an insufficient amount of memory is assigned to the virtual machine. It is important to be aware of the application and service needs before making changes throughout a data center.
The various sizing considerations can be reviewed at this Hyper-V sizing white paper.

Network configurations *
Virtual network configurations are configured in the Virtual Network Manager in the Hyper-V GUI or in the System Center virtual machine Manager in the properties of a physical server. There are three types of virtual networks:
- **External**: An external network is mapped to a physical NIC to allow virtual machines access to one of the physical networks that the parent partition is connected. Essentially, there is one external network and virtual switch per physical NIC.
- **Internal**: An internal network provides connectivity between virtual machines, and between virtual machines and the parent partition.
- **Private**: A private network provides connectivity between virtual machines only.
The solution network requirements for the specific scenarios must be understood before configuring the network of various types. * Source – Network configuration information is referred from https://technet.microsoft.com/en-us/library/cc754263.aspx

Live Migration—Implementation considerations
Besides the Hyper-V-specific implementation considerations, a few Live Migration-specific considerations are summarized below:

**Live Migration—A managed operation**
Live migration is a managed failover operation of VM resources. Meaning, it must be performed when all the solution components are in a healthy state. All the servers and systems are running and all the links are up. Since this is a managed failover operation, ensure that the management tasks and IO load are minimal to the server and storage. It is recommended to ensure that the underlying infrastructure is in healthy state before performing a live migration. However, CLX has the capability of discovering any storage level conditions unfavorable for performing live migrations. In response to such a situation, CLX stops/cancels live migration process and informs the user. This is also handled in a way that it does not cause VM downtime. For example, if a live migration is initiated while VM data residing on the storage arrays is still merging and the data between both storage arrays is not in sync, CLX proactively cancels the live migration and informs the user to wait until the merge is finished. In the absence of this feature, it would be possible that a live migration fails or the VM comes online in the remote data center with inconsistent data.

Networking Considerations: There must be a dedicated network configured in a cluster for live migration traffic. It is recommended to dedicate a 1 Gigabit Ethernet connection for the live migration network between cluster nodes to transfer the large number of memory pages typical for a virtual machine.

Configure all hosts that are part of Failover Clustering on the same TCP/IP subnet. Failover clustering supports different IP addresses used in different data centers through the OR relationship implementation of IP address resources. However, to use Live Migration the VM needs to keep the same IP address across data centers to achieve the goal of continuous access from clients to the virtual machine during and after the migration. That means the same IP subnet must be stretched across data centers for Live Migration to work across data centers without connectivity loss. Several options are available from HPE to achieve this goal.

**Virtual Machine and LUN Mapping Considerations**
Microsoft Failover Clustering in Windows Server 2012/2012 R2 allows simultaneous live migration of VMs, where as in Windows Server 2008 R2 allows live migration for only one VM between a single source and destination server within a cluster. In other words, any cluster node server can be part of only one Live Migration as a source or destination.

On the storage side, a remote copy replication group is the atomic unit of failover. It is important to maintain a 1-to-1 mapping between a VM and a replication storage group. In configurations where multiple VMs are hosted on the same LUN (or replication group), live migration of one VM can affect others and hence are not recommended.
Distance considerations
The supported distance for the Hyper-V Live Migration in a CLX configuration depends on various parameters such as inter-site link bandwidth and latency (distance), the VM configurations, the type of storage based replication, distance considerations for MSFC and so on. For specific information, refer to the following links:  

Note:
CLX supports Synchronous Storage based replication only for Live Migration, for quick migration CLX supports both Synchronous and Asynchronous storage based replication modes.

Storage replication groups per VM considerations in CLX environment
Typically, a virtual machine uses a single dedicated LUN for VM data (guest operating system) and multiple LUNs for the application data. All these LUNs needs to be part of the same remote copy replication group. LUN for the application data can be presented as pass through disk in 2008R2 or directly to guest OS in VM using Hyper-V Virtual Fibre channel technology in 2012/2012 R2.

Supported scenarios for Live Migration in a non CSV environment
The following Live Migration scenarios are supported with CLX:

Scenario A: Disaster recovery and high availability for virtual machine
This is a prominent scenario where the VM is hosted on a standard Windows Server 2008 R2/2012/2012 R2 (host OS/Host partition) and it is clustered with another similar host OS. Whenever any failure/planned migration is detected by the cluster, the VM can failover/live migrate from one server cluster node to another. Every time the failover/live migration is performed across the nodes, CLX takes appropriate actions to make replicated storage accessible and highly available.

The following diagram is an illustration of this scenario. A multi-site replicated disk is presented to two Hyper-V parent partitions that are clustered using Windows Failover Cluster. Each of the parents OS resides on each site. VM is created on the replicated disk and the VM is added to the Failover Cluster as a service group/Role on the parent partition. When a failure/live migration operation is detected by the Failover Cluster, Failover Cluster live migrates the VM to the other cluster node either within the same datacenter or across the datacenter and CLX ensures that remote copy storage replication direction is changed and the storage disk is made write enabled when VM migrates across DC (If VM migrates with datacenter, then CLX makes VM come online without performing storage failover).

Figure 5: Scenario A—before live migration
Scenario B: Disaster recovery and high availability for virtual machine and applications hosted by virtual machine in a non CSV environment

This is an extension of scenario A. This scenario considers that there is an application hosted by the VM. Also, assume that this application uses replicated SAN storage for disaster recovery. When the VM fails over/live migrates, the application also fails over along with it to other server cluster node. After failover/live migration, for VM and application to come online, disk read/write access must be made available. This can be achieved through replicated disks and failover through CLX. The way this would work is to have a multiple Virtual Volumes (VVs) in one remote copy replication group. One VV for hosting the VM and the remaining VVs to host the application data inside the VM.

The following diagrams are an illustration of scenario B.

**Pass through scenario for Windows 2008 R2:** Two multi-site replicated disks part of the same remote copy replication group are presented to two Hyper-V parent partitions that are clustered using Windows Failover Cluster. On the parent partition, a VM is created on one of the disk and the other disk used as data disk for the application hosted by VM is configured as Pass Through disk to Guest OS.

The VM is added to the Failover Cluster as a service group. CLX resource is created for this service group. Both OS disk and Pass through disks are made dependent on CLX resource. When a failure/live migration is detected by the Failover Cluster, Failover Cluster moves the VM disk and with it the application disk to the other cluster node and CLX ensures that remote copy storage replication direction is changed hence achieving automatic failover and high availability. Follow the similar procedure for CLX dependency if you want to add additional application disks to the VM.

After configuration is done, to validate the configuration generate the VM dependency report in failover cluster manager.
Figure 7: VM dependency report for Windows 2008 R2

Figure 8: Scenario B with Pass through disk—before live migration
**Figure 9:** Scenario B with Pass through disk—after live migration

VFC scenario for Windows 2012/2012 R2/2016: Two multi-site replicated disks are part of same remote copy replication group. One of the replicated disks meant for VM creation is presented to two Hyper-V parent partitions that are clustered using Windows Failover Cluster. On the parent partition, a VM is created on the replicated disk. Second replicated disk is presented to Guest OS through VFC, which will be used as data disk for the application hosted by VM. The VM is added to the Failover Cluster as a Role. CLX resource is created inside this role. OS disk is made dependent on CLX resource. When a failure/live migration is detected by the Failover Cluster, Failover Cluster moves the VM disk and with it the application disk will also move to the other cluster node and CLX ensures that remote copy storage replication direction is changed. Hence, it helps in achieving automatic failover and high availability. Multiple replicated Disks can be presented to Guest OS for application data through VFC directly. Ensure these disks are part of same remote copy replication group where VM disk resides. Disks presented through VFC to guest OS will not be visible in dependency report as they will not be visible in the Host OS (Parent partition).

**Figure 10:** VM dependency report for Windows server with VFC
Figure 11.1: Scenario B through VFC disk—before live migration

Figure 11.2: Scenario B through VFC disk—after live migration
Scenario C – Live migration of Virtual Machines on a CSV disk

This is a prominent scenario where the multiple VMs are hosted on a CSV disk in a Windows Server 2012/2012 R2/2016 cluster environment. CSV gives the ability to store multiple VHDs on a single LUN and run the associated VMs on any cluster node. Additionally, CSV enables Live Migration which allows to move a running VM from one node to another node. Since disk ownership no longer needs to change when a VM moves to another node, this makes the process quicker and safer.

In a multi-site storage array replicated environment, CSV disks are replicated to the remote datacenter using the array-based remote copy replication feature. VMs residing in the CSV disk can run on any cluster nodes (physical servers). In case of disaster to the primary datacenter, CSV disks need to be brought online in the secondary datacenter. For this, storage failover needs to be done after checking the CLX disaster recovery rules before cluster brings the CSV disk online. This is where CLX comes into picture to swap replication direction and perform the storage failover in an automated fashion to add failover capabilities for the CSV disks in the clustering environment.

During the planned migration scenario, VMs on the CSV disks can be live migrated to different nodes either within the same datacenter or across the datacenter. For detailed information, see “Virtual Machine Management hosted on a Cluster Shared Volume on Windows Server 2012/2012 R2/2016” section in HPE 3PAR StoreServ Cluster Extension Software Administrator Guide.

VMs residing on the CSV disks with application disks mapped through VFC on Windows 2012/2012 R2/2016

CSV and VFC disks are part of different 3PAR remote copy replication groups. Remote copy replicated disk meant for CSV is presented to two Hyper-V parent partitions that are clustered using Windows Failover Cluster. VMs are created on the remote copy replicated CSV disk. A CLX resource needs to be created and configured to manage the CSV disk. Remote copy replicated disks meant for VFC disks are presented to VMs through VFC, which are used as data disks for the applications hosted by VMs. A separate CLX resource needs to be created and configured to manage the VFC disks residing inside each remote copy group. This means that if VMs from two remote copy groups are used to create VFC disks. Then two CLX resources need to be created and configured, one to manage each remote copy group. Also, no two VMs should have the VFC disks coming out of the same 3PAR remote copy group. All the VFC disks configured for a VM can come out of a single 3PAR remote copy group or multiple remote copy groups depending upon the user configuration for the applications. For every remote copy group, a separate CLX resource needs to be created and configured.

You need CLX resource to manage CSV disk. VMs residing on a CSV disk can be running on the same failover cluster node as the CSV disk or the VMs and the CSV disk can be running on a different failover cluster nodes. These nodes can be in the same datacenter or across datacenters.

Remote Copy group replication mode for the VFC disks must be synchronous replication mode only and the replicated virtual volumes of the remote copy group should have the same WWNs.

When user performs the live migration of the VMs residing on a CSV disk, CLX resource configured for the VFC disks ensures that remote copy replication direction is changed for the VFC disks. Upon completion of remote copy replication direction change, the VMs comes online enabling the applications on the VM to perform the IOs on the VFC disks. With this configuration, you can achieve the Live Migration of VMs residing on CSV disk with VFC disks configured to VMs.

CLX provides an option for VMs residing on CSV disk to be in the same datacenter or different datacenter as the CSV disk. This can be achieved using CLX VM management functionality. Refer to the HPE 3PAR StoreServ Cluster Extension Software Administrator Guide to configure the CLX resource for CSV and CLX VM management functionality.

The VMs residing on a CSV disk has the following two configuration options:

Option A: VMs not using the CLX VM Management functionality

Option B: VMs using the CLX VM Management functionality

Before performing the Live Migration of the VMs, make sure that remote copy group state of VFC disks and remote copy group state of CSV is in started and the remote copy volumes state is in synced state.
Option A: VMs not using the CLX VM Management functionality

With this option, you can have the configuration, where in the VMs of the CSV disk run on same or different failover cluster nodes, which could be in the same or across the datacenters. CSV disk can be owned by the failover cluster node which is in the same or different datacenter where VMs are running.

As part of the configuration, VM is created on the CSV disk and a new remote copy group is created for the VFC disks. The volumes from the remote copy group are mapped to the VM using VFC. A new CLX resource is created and configured in the VM role of the failover cluster. The CLX resource (CLX_For_VFC as shown in the following dependency diagram) is configured to manage the remote copy group of the VFC disks. You have to set the dependency of the Virtual Machine configuration to depend on the CLX resource as shown in the following diagram. This dependency ensures that when you perform the live migration of VM across the datacenters, first the CLX resource performs the storage failover operation for the VFC disks, and then only the associated VM comes online enabling the application running on the VMs to perform the IOs on the VFC disks.

Figure 12.1: VM dependency report for Windows server with VFC

In the following figure 12.2, VM is residing on a CSV disk, which is from a remote copy group RCG1. This VM has application disk mapped using the VFC and the volumes for this VFC disks are from a different remote copy group RCG2. The data is getting replicated from Site A to Site B as depicted in the figure. CSV disk and the VM of the CSV disk are running from a same failover node in Site A.
Once you perform the live migration of the VM on the CSV disk, the configuration after live migration, is as shown in the figure 12.3. The VM with VFC disks is running from a failover cluster node in Site B and performing the application IOs. These IOs from the application VFC disks are getting replicated from Site B array to Site A array. But, VM is running in a redirected access mode, where in the VM data is copied over the Ethernet link to the CSV disk owned node and this node does the IO from the VM to the volume of the remote copy group on the Site A array. The VMs data gets replicated from Site A array to Site B array.
Figure 12.3: Option A through VFC disk—after live migration
If CSV disk itself is migrated from site A to site B, CLX resource configured for CSV takes care of performing the storage failover operation for the CSV disk. But the VMs do not move/migrate during this situation.

Option B: VMs using the CLX VM Management functionality
With this option, you can have the configuration, where in the VMs of the CSV disk are running on failover cluster nodes, which are in the same datacenter as the datacenter where CSV owning node resides. CLX VM management functionality always ensures that the VMs and the CSV disk are owned by the failover cluster nodes in the same datacenter.

As part of the configuration, VM is created on the CSV disk. CLX VM management resource is added to the VM role and the dependency is set accordingly. Refer to the HPE 3PAR StoreServ Cluster Extension Software Administrator Guide to configure the CLX resource for CSV and CLX VM management functionality.

A new remote copy group is created for the VFC disks. The volumes from the remote copy group are mapped to the VM using the VFC. A new CLX resource is created and configured in the VM role of the failover cluster. The CLX resource (CLX_VFC as shown in the following dependency diagram) is configured with the remote copy group of the VFC disks. You have to set the dependency of the Virtual Machine configuration to depend on the CLX resource (CLX_VFC) and CLX resource (CLX_VFC) dependent on the CLX VM management resource as shown in the following diagram.

**Figure 12.4: VM dependency report for Windows server with VFC**

In the following figure 12.5, VM is residing on a CSV disk, which is from a remote copy group RCG1. This VM has disk mapped using the VFC and the volumes for this VFC disk are from a different remote copy group RCG2. The data is getting replicated from Site A to Site B as depicted in the figure. CSV disk and the VM of the CSV disk are running from a same failover node in Site A.
With CLX VM Management functionality configured for the VM residing on the CSV disk, you cannot perform the live migration of the VM across the site, but you can move the CSV disk across the sites. When you initiate the CSV disk movement across the site, the CLX resource, which is managing the CSV disk performs the storage failover to swap replication direction for the remote copy group configured for the CSV disk and CSV disk comes online successfully. Once the CSV disk comes online successfully, the CLX VM management resource of the VM role initiates the live migration of VM to one of the failover cluster nodes in the site where CSV disk is also owned. As part of the live migration of VM, the CLX resource (CLX_VFC) managing the VFC disk remote copy group performs the storage failover to swap replication direction of the remote copy group configured for the VFC disks. Once the storage failover is completed, the VM comes online enabling the application to perform the I/Os on the VFC disks.

This dependency shown in the figure 12.6 ensures that when the VM is live migrated to a failover cluster node across the datacenters, first the VFC disk completes the storage failover successfully, and then only the associated VM comes online enabling the application running on the VMs to perform the application I/Os on the VFC disks.
Once CSV disk is moved across the datacenters and VM residing on the CSV disk completes the live migration, the configuration is as shown in the figure 12. The VM with VFC disks is running from a failover cluster node in Site B and performing the application IOs. These IOs are getting replicated from Site B array to Site A array. Also, the VM data gets replicated from Site B array to Site A array.
Step-by-step guide to deploy CLX Solution
This section describes the major steps required to build a 3PAR CLX solution. The steps are described in brief and for more details refer to relevant product manuals and specifications.
The section assumes the configuration as depicted in Figure 13.

Figure 13: Typical HPE 3PAR CLX solution configuration

The Figure 13 configuration involves a two-node File Share Witness (FSW) cluster with one node in each of the sites and third node with file share for arbitration in the third site. CLX supports the use of FSW or Node Majority cluster configuration. It is also recommended to enable redundancy for each component at each site. The inter-site links must be in redundant configuration so as not to have any Single Point of Failure (SPOF). For details on SAN configuration, refer to the HPE SAN Design Guide. A link to the SAN Design Guide is provided in the references section at the end of this document. Make sure that all the component, such as Server, Storage, HBA, Switch and software is supported by referring to HPE’s SPOCK website.

Deploying Windows Server 2008 R2/2012/2012 R2/2016 Hyper-V
For 2008 R2, see “Deploying Windows Server 2008 Hyper-V on ProLiant servers” of HPE white paper “Implementing Microsoft Windows Server 2008 Hyper-V on HPE ProLiant servers”:
http://h20566.www2.HPEe.com/HPEsc/doc/public/display?docId=emr_na-c01516156
For 2012/2012 R2/2016, see “Implementing Microsoft Windows Server on HPE ProLiant servers” whitepaper:
Installing Hyper-V role
For 2008 R2, see the section “Installing Windows Server 2008 Hyper-V server role” of the HPE white paper “Implementing Microsoft Windows Server 2008 Hyper-V on HPE ProLiant servers”. To install the Hyper-V role on Server Core, run the following command:

```
start /w OCSetup Microsoft-Hyper-V
```

After the command completes, reboot the server to complete the installation. After the server reboots, run the oclist command to verify the role is installed.


Creating geographically-dispersed Node and File Share Majority cluster

• Before forming a cluster, make sure the nodes meet the following requirements:
  o Hyper-V role is installed.
  o Perform ‘Pre-Installation procedures’ mentioned in the HPE 3PAR CLX installation guide.

• For creating Failover Cluster in 2008 R2, follow the instructions at: https://technet.microsoft.com/en-us/library/cc730647.aspx


Installing HPE 3PAR Command Line Interface
For installing HPE 3PAR command line interface see “Installing the HPE 3PAR Command Line Interface” section in “HPE 3PAR Command Line Interface Administrator's Manual”

Install HPE 3PAR CLX software
For installing HPE 3PAR CLX software see “HPE 3PAR StoreServ Cluster Extension Software Installation Guide”

Configure Virtual Networks
From Hyper V Manager, connect to both cluster nodes and Create virtual networks as appropriate for the setup. To get more details on how to configure Virtual networks, see the links:


Provisioning storage for a virtual machine
Before creating the virtual machine, both cluster nodes must be provisioned with an array based replication disks from the respective 3PAR array. For example, (see Figure 13) LUN from 3PAR1 must be presented to Host in Site A and LUN from 3PAR 2 must be presented to Host in Site B and both LUN must be part of the same Remote copy group. Ensure that both VM disk (VV) and Data disk (VV) are part of the same Remote Copy group. For more details, see “Remote Copy Software User Guide” link mentioned below. Use 3PAR SSMC UI/Command Line interface (3PAR CLI) create a remote copy group, create Virtual Volumes (VV) and add VVs to the same Remote copy groups.


• HPE 3PAR Command Line Interface Reference: http://h20564.www2.HPEe.com/HPEsc/doc/public/display?docld=c04204279

• HPE 3PAR StoreServ Management Console (SSMC) Administrator’s Guide: http://h20564.www2.HPEe.com/HPEsc/doc/public/display?docld=c04777556

• Initialize the provisioned disk in Computer management and bring it online. For more information, see “HPE 3PAR StoreServ Cluster Extension Software Installation Guide”
• From Failover cluster Manager add disk to Cluster Storage.

Creating and configuring highly available virtual machine

• The Virtual Machine data must reside on a multi-site/storage-replicated disk provisioned in the step above. This is to ensure that VM-related data is available and accessible to all cluster nodes in the event of failover.
• To create a virtual machine follow the steps mentioned below:
  • In Failover Cluster Manager, select or specify the cluster that you want. Ensure that the console tree under the cluster is expanded. Click Roles/Services and Application and in the Actions pane, click Virtual Machines, and then click New Virtual Machine. The New Virtual Machine Wizard appears. Click Next.
  • In the Wizard, select the ‘provisioned disk’ as location for Virtual Machine. Select the earlier configured virtual network for networking.
A Windows operating system image located locally is attached for installing the operating system on the virtual machine. For Windows 2008 OS requirements see https://technet.microsoft.com/en-us/windowsserver/bb414778.aspx
Configuring HPE 3PAR CLX Software
For configuring HPE 3PAR CLX software see “Configuring HPE 3PAR StoreServ Cluster Extension” section in “HPE 3PAR StoreServ Cluster Extension Software Administrator Guide”

Creating a CLX resource from failover cluster manager
Select the Virtual Machine and in the Actions Pane, Add a resource -> More resources -> Add Cluster Extension 3PAR

Figure 18: Creating CLX resource for VM

<table>
<thead>
<tr>
<th>Name</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Machine</td>
<td></td>
</tr>
<tr>
<td>Virtual Machine LVM02</td>
<td>Running</td>
</tr>
<tr>
<td>Virtual Machine Configuration LVM02</td>
<td>Online</td>
</tr>
<tr>
<td>Disk Drives</td>
<td></td>
</tr>
<tr>
<td>Cluster Disk 1</td>
<td>Online</td>
</tr>
<tr>
<td>Other Resources</td>
<td></td>
</tr>
<tr>
<td>New Cluster Extension 3PAR</td>
<td>Offline</td>
</tr>
</tbody>
</table>

A CLX resource is created for the selected virtual machine. Steps to Configure CLX resource properties are as follows:

Double click the CLX resource.

Rename the CLX resource.

Select the HPE 3PAR StoreServ CLX settings tab and configure the CLX resource properties. For details see “HPE 3PAR StoreServ Cluster Extension Software Administrator Guide”

A completed CLX resource configuration can be viewed in the resource property tab as shown in the Figure 19.

Figure 19: CLX Resource properties for VM
Set the VM disk dependency on CLX resource

Set a dependency of the VM Disk on CLX resource before bring the CLX resource online. For more information, see “Configuring HPE 3PAR StoreServ Cluster Extension” section in “HPE 3PAR StoreServ Cluster Extension Software Administrator Guide.”

**Figure 20:** Setting VM disk dependency on CLX resource

![Image of dependency report]

After creating CLX resource, the dependency report appears similar to the dependency report shown in the following figure.

**Figure 21:** VM Resource dependency

![Image of VM dependency]

Now CLX configuration for the VM is completed, VM can be brought online, ensure that VM comes online successfully.

Once VM comes online perform live migration on the VM.

It is advisable to validate the configuration by performing some test Live Migration to make sure that the solution is behaving as expected.

In Microsoft failover cluster manager, select the Virtual Machine for live migration, in the Actions pane.

In 2008 R2, click on Live Migrate Virtual Machine to another node and select the cluster node to live migrate.

In 2012/2012 R2/2016, click on Move-> Live Migration -> Select node.

This will initiate the live migration of the VM to the selected node.
Figure 22: Virtual Machine Live migration test

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Configuring Pass Through disk for VM in Windows Server 2008 R2

Pass through disk can be added as a data disk for the application hosted by the VM

Create and Add Disk to host

From SSMC/3PAR CLI

- Create new Virtual Volume (VV) on both Primary and Secondary site 3PAR arrays.
- Add the newly created VV to same Remote copy group where the VM VV resides.
- Present newly created Primary and Secondary VVs to the failover cluster nodes in respective Datacenter.

Follow the steps mentioned in the following link on “How to Add a Pass through disk on a Failover Cluster” at:

---

Figure 23: Pass through disk (Cluster Disk 2) configured for VM

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Once the Pass through disk is added, make Pass through Disk also dependent on CLX resource.
Now both VM disk and Pass through disks are dependent on CLX resource.
To add more Pass through disks, repeat the above mentioned steps.

Log in to Guest OS (VM) and verify the availability of Pass through disk as a disk in Guest OS Disk management.
Configuring VFC disk for VM in Windows Server 2012/2012 R2/2016

Disks from the storage array can be directly added to Guest OS by implementing Hyper-V Virtual Fibre Channel on both hosts. To implement Hyper-V Virtual Fibre channel, see the website: https://technet.microsoft.com/en-in/library/dn551169.aspx

Create Disk and add Disk to Guest OS
Using SSMC/3PAR CLI
  o Create new Virtual Volumes (VVs) on both Primary and Secondary site 3PAR arrays.
  o Add the newly created VVs to same Remote copy group where the VM VV resides.
  o Create Host in the 3PAR array for Guest OS (Using VFC WWNs)
  o Present the new VVs through VFC feature to Guest OS from both 3PAR arrays.

To add more VFC disks to Guest OS repeat the above mentioned steps.
Log in to Guest OS (VM) and verify the availability of the VFC Disk as a disk in Guest OS Disk management.

Figure 27: VFC Disk in Guest OS
Live migration process in CLX environment
The live migration process is designed to move a running VM from the source physical host to a destination physical host as quickly as possible.

When live migration process is initiated:
- Live migration setup stage starts and the source server creates a connection with the destination server. This connection transfers the virtual machine configuration data to the destination server. A skeleton virtual machine is set up on the destination server and memory is allocated to the destination virtual machine.
- Memory assigned to the migrating virtual machine (Working Set) starts getting copied over the network to the destination server.
- Meanwhile, CLX detects the ongoing live migration event and validates if Storage is in favorable condition for live migration or not. If the Storage is in favorable condition, CLX continues with the Live Migration process. If the Storage is not in favorable condition, CLX stops or cancels the Live Migration process without bringing down the VM.
- Live Migration process continues to transfer modified memory pages, CPU, and device state of the virtual machine to the destination server.
- After the modified memory pages are copied completely to the destination server, the destination server has an up-to-date working set for virtual machine.
- Before bringing virtual machine and associated application disks online on destination node, CLX performs storage failover operation and makes virtual machine and associated application data disks present in the 3PAR remote copy group of the destination array read-write.
- CLX resource comes online on the destination server, which in turn brings dependent virtual machine and disk resources online (See Figure 21: VM resource dependency).
- In the final stage of a live migration, the migrated virtual machine is running on the destination server. At this point, a message is sent to the network switch. This message causes the network switch to obtain the new MAC addresses of the migrated virtual machine so that network traffic to and from "virtual machine" can use the correct switch port.
- The live migration process completes in less time than the TCP time-out interval for the virtual machine being migrated. TCP time-out intervals vary based on network topology and other factors.

In your CLX environment, perform the live migration test for the virtual machines across datacenters and check whether live migration is completing within the TCP time-out interval, which is suitable for your virtual machine and its application workloads. If live migration exceeds the TCP time-out interval clients may lose the connection to virtual machine, however virtual will be available online on target node, to continue the access, the clients needs to be connected again.
When performing simultaneous live migration of virtual machines across datacenters, check whether live migration of multiple virtual machine is within the TCP time-out interval which is suitable for your virtual machines and its application workloads.

*Source – Live migration process information is referred from following link https://technet.microsoft.com/en-in/library/hh831435.aspx
Appendix A – References

Step-by-Step Guide for Testing Hyper-V and Failover Clustering

Hyper-V and Live Migration Whitepaper.pdf
windows_server_2012_r2_server_virtualization_white_paper.pdf

Hyper-V: Using Hyper-V and Failover Clustering

Deploy a Hyper-V Cluster 2012

Creating a Failover Cluster 2008 R2

HPE Single Point of Connectivity Knowledge (SPOCK) https://h20272.www2.hp.com/sпock/

SAN Design Guide

Disaster-tolerant solutions with HPEE 3PAR Remote Copy

HPE 3PAR MPIO Software for Microsoft Windows

HPEE 3PAR Remote Copy Software User Guide

HPEE 3PAR Command Line Interface Reference
http://h20564.www2.hp.com/HPEsc/doc/public/display?docId=c04204279

HPE 3PAR StoreServ Management Console (SSMC) Administrator's Guide
http://h20564.www2.hp.com/HPEsc/doc/public/display?docId=c04777556

Virtual Machine Live Migration Overview


Hyper-V Virtual Fibre Channel Overview

Implement Hyper-V Virtual Fibre Channel