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Master's guide to VMware Fault Tolerance

Posted by: [Eric Siebert](#)

[VMware](#), [Fault Tolerance](#), [High Availability](#)



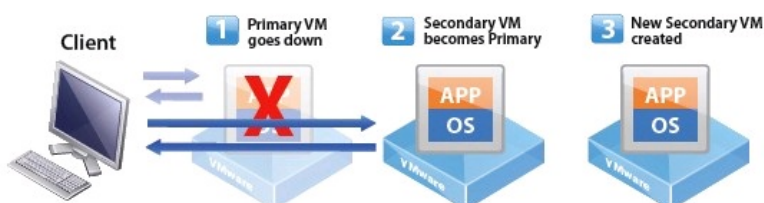
I've written about the vSphere's new Fault Tolerance (FT) feature several times and wanted to put the information together in one blog, as well as include some new information. We've broken this guide into several sections as it's a bit lengthy, so you can skim the witty titles and decide if a section for you, or if you'd rather keep on truckin' to the next section. But first, if you'd like to check out my previous posts on FT, they are available here:

- [VMware Fault Tolerance: What it is and how it works](#)
- [New SiteSurvey utility from VMware checks for Fault Tolerance compatibility](#)
- [More details on VMware's Fault Tolerance feature](#)

I. And VMware said, 'Let there be Fault Tolerance'

Fault Tolerance was introduced as a new feature in vSphere that provided something that was missing in VMware Infrastructure 3 (V3), the ability to have continuous availability for a virtual machine in case of a host failure. High Availability (HA) was a feature introduced in V3 to protect against host failures, but it caused the VM to go down for a short period of time while it was restarted on another host. FT takes that to the next level and guarantees the VM stays operational during a host failure by keeping a secondary copy of it running on another host server. If a host fails, the secondary VM becomes the primary VM and a new secondary is created on another functional host.

The primary VM and secondary VM stay in sync with each other by using a technology called Record/Replay that was first introduced with VMware Workstation. Record/Replay works by recording the computer execution on a VM and saving it as a log file. It can then take that recorded information and replay it on another VM to have a replica copy that is a duplicate of the original VM.



II. Power to the processors

The technology behind the Record/Replay functionality is built in to certain models of Intel and AMD processors. VMware calls it vLockstep. This technology required Intel and AMD to make changes to both the performance counter architecture and virtualization hardware assists (Intel VT and AMD-V) that are inside the physical processors. Because of this, only newer processors support the FT feature. This includes the third-gen AMD Opteron based on the AMD Barcelona, Budapest and Shanghai processor families, and Intel Xeon processors based on the Penryn and Nehalem micro-architectures and their successors. VMware has published a

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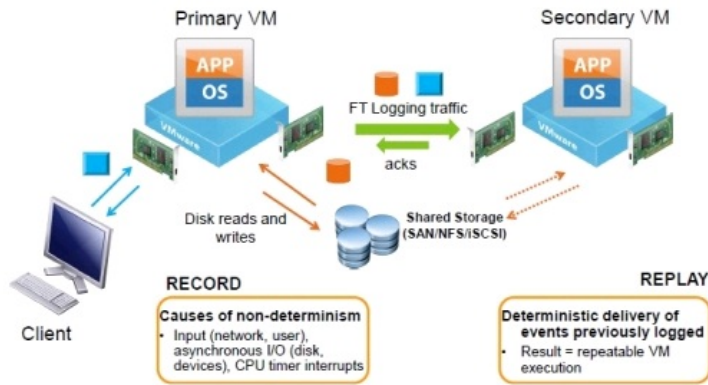


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[knowledgebase article](#) that provides more details on this.



III. But how does it do that?

FT works by creating a secondary VM on another ESX host that shares the same virtual disk file as the primary VM, and then transferring the CPU and virtual device inputs from the primary VM (record) to the secondary VM (replay) via a FT logging network interface card (NIC) so it is in sync with the primary VM and ready to take over in case of a failure. While both the primary and secondary VMs receive the same inputs, only the primary VM produces output such as disk writes and network transmits. The secondary VM's output is suppressed by the hypervisor and is not on the network until it becomes a primary VM so essentially both VMs function as a single VM.

It's important to note that not everything that happens on the primary VM is copied to the secondary VM. There are certain actions and instructions that are not relevant to the secondary VM, and to record everything would take up a huge amount of disk space and processing power. Instead, only non-deterministic events are recorded, which include inputs to the VM (disk reads, received network traffic, keystrokes, mouse clicks, etc.) and certain CPU events (RDTSC, interrupts, etc.). Inputs are then fed to the secondary VM at the same execution point so it is in exactly the same state as the primary VM.

The information from the primary VM is copied to the secondary VM using a special logging network that is configured on each host server. This requires a dedicated gigabit NIC for the FT Logging traffic (although not a hard requirement, this is highly recommended). You could use a shared NIC for FT Logging for small or test/dev environments and for testing the feature. The information that is sent over the FT Logging network between the host can be very intensive depending on the operation of the VM.

VMware has a formula that you can use to determine this:

VMware FT logging bandwidth \approx (Avg disk reads (MB/s) \times 8 + Avg network input (Mbps)) \times 1.2 [20% headroom]

To get the VM statistics needed for this formula you need to use the performance metrics that are supplied in the vSphere client. The 20% headroom is to allow for CPU events that also need to be transmitted and are not included in the formula. Note that disk or network writes are not used by FT as these do not factor in to the state of the virtual machine.



As you can see, disk reads will typically take up the most bandwidth. If you have a VM that does a lot of disk reading you can reduce the amount of disk read traffic across the FT Logging network by using a special VM parameter. By adding a `replaylogReadData = checksum` parameter to the VMX file of the VM, this will cause the secondary VM to read data directly from the shared disk, instead of having it transmitted over the FT logging network. For more information on this see this [knowledgebase article](#).

IV. Every rose has its thorn

While Fault Tolerance is a useful technology, it does have many requirements and limitations that you should be aware of. Perhaps the biggest is that it currently only supports single vCPU VMs, which is unfortunate as many big enterprise applications that would benefit from FT usually need multiple vCPU's (vSMP). Don't let this discourage you from running FT, however, as you may find that some applications will run just fine with one vCPU on some of the newer, faster processors that are available as detailed [here](#). Also, VMware has mentioned that support for vSMP will come in a future release. It's no easy task trying to keep a single vCPU in lockstep between hosts and VMware developers need more time to develop methods to try and keep multiple vCPUs in lockstep between hosts. Additional requirements for VMs and hosts are as follows:

Host requirements:

- CPUs: Only recent HV-compatible processors (AMD Barcelona+, Intel Harpertown+), processors must be the same family
- All hosts must be running the same build of VMware ESX
- Storage: shared storage (FC, iSCSI, or NAS)
- Hosts must be in an HA-enabled cluster
- Network and storage redundancy to improve reliability: NIC teaming, storage multipathing
- Separate VMotion NIC and FT logging NIC, each Gigabit Ethernet (10 GB recommended). Hence, minimum of 4 NICs (VMotion, FT Logging, two for VM traffic/Service Console)

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- * CPU clock speeds between the two ESX hosts must be within 400 Mhz of each other.

VM requirements:

- * VMs must be single-processor (no vSMP)
- * All VM disks must be "thick" (fully-allocated) and not thin; if a VM has a thin disk it will be converted to thick when FT is enabled.
- * No non-replayable devices (USB, sound, physical CD-ROM, physical floppy, physical Raw Device Mappings)
- * Make sure paravirtualization is not enabled by default (Ubuntu Linux 7/8 and SUSE Linux 10)
- * Most guest operating systems are supported with the following exceptions that apply only to hosts with third generation AMD Opteron processors (i.e. Barcelona, Budapest, Shanghai): Windows XP (32-bit), Windows 2000, Solaris 10 (32-bit). See [this KB article](#) for more.

In addition to these requirements your hosts must also be licensed to use the FT feature, which is only included in the Advanced, Enterprise and Enterprise Plus editions of vSphere.

V. How to use Fault Tolerance in your environment

Now that you know what FT does, you'll need to decide how you will use it in your environment. Because of high overhead and limitations of FT you will want to use it sparingly. FT could be used in some cases to replace existing Microsoft Cluster Server (MSCS) implementations, but it's important to note what FT does not do, which is to protect against application failure on a VM. It only protects against a host failure.

If protection for *application* failure is something you need, then a solution like MSCS would be better for you. FT is only meant to keep a VM running if there is a problem with the underlying host *hardware*. If protecting against an *operating system* failure is something you need, then VMware High Availability (HA) is what you want, as it can detect unresponsive VMs and restart them on the same host server.

FT and HA can be used together to provide maximum protection. If both the primary host and secondary host failed at the same time, HA would restart the VM on another operable host and spawn a new secondary VM.

VI. Important notes

One important thing to note: If you experience an OS failure on the primary VM, like a Windows Blue Screen Of Death (BSOD), the secondary VM will also experience the failure as it is an identical copy of the primary. The HA virtual machine monitor will detect this, however, restart the primary VM, and then spawn a new secondary VM.

Another important note: FT does not protect against a storage failure. Since the VMs on both hosts use the same storage and virtual disk file it is a single point of failure. Therefore it's important to have as much redundancy as possible to prevent this, such as dual storage adapters in your host servers attached to separate switches, known as multi-pathing). If a path to the SAN fails on one host, FT will detect this and switch over to the secondary VM, but this is not a desirable situation. Furthermore if there was a complete SAN failure or problem with the VMs LUN, the FT feature would not protect against this.

VII. So should you actually use FT? Enter SiteSurvey

Now that you've read all this, you might be wondering if you meet the many requirements to use FT in your own environment. VMware provides a utility called [SiteSurvey](#) that will look at your infrastructure and see if it is capable of running FT. It is available as either a Windows or Linux download and once you install and run it, you will be prompted to connect to a vCenter Server. Once it connects to the vCenter Server you can choose from your available clusters to generate a SiteSurvey report that shows whether or not your hosts support FT and if the hosts and VMs meet the individual prerequisites to use the feature.

You can also click on links in the report that will give you detailed information about all the prerequisites along with compatible CPU charts. These links go to VMware's website and display the [help document](#) for the SiteSurvey utility, which is full of great information, including some of the following prerequisites for FT.

- * The vLockstep technology used by FT requires the physical processor extensions added to the latest processors from Intel and AMD. In order to run FT, a host must have an FT-capable processor, and both hosts running an FT VM pair must be in the same processor family.
- * When ESX hosts are used together in an FT cluster, their processor speeds must be matched fairly closely to ensure that the hosts can stay in sync. VMware SiteSurvey will flag any CPU speeds that are different by more than 400 MHz.
- * ESX hosts running the FT VM pair must be running at least ESX 4.0, and must be running the same build number of ESX.
- * FT requires each member of the FT cluster to have a minimum of two NICs with speeds of at least 1 Gb per second. Each NIC must also be on the same network.
- * FT requires each member of the FT cluster to have two virtual NICs, one for logging and one for VMotion. VMware SiteSurvey will flag ESX hosts which do not contain at least two virtual NICs.
- * ESX hosts used together as a FT cluster must share storage for the protected VMs. For this reason VMware SiteSurvey lists the shared storage it detects for each ESX host and flags hosts that do not have shared storage in common. In addition, a FT-protected VM must itself be stored on shared storage and any disks connected to it must be shared storage.
- * At this time, FT only supports single-processor virtual machines. VMware SiteSurvey flags virtual machines that are configured with more than one processor. To use FT with those VMs, you must reconfigure them as single-CPU VMs.
- * FT will not work with virtual disks backed with thin-provisioned storage or disks that do not have clustering features enabled. When you turn on FT, the conversion to the appropriate disk format is performed by default.
- * Snapshots must be removed before FT can be enabled on a virtual machine. In addition, it is not possible to take snapshots of virtual machines on which FT is enabled.
- * FT is not supported with virtual machines that have CD-ROM or floppy virtual devices backed by a physical or remote device. To use FT with a virtual machine with this issue, remove the CD-ROM or floppy virtual device or reconfigure the backing with an ISO installed on shared storage.
- * Physical RDM is not supported with FT. You may only use virtual RDMs.
- * Paravirtualized guests are not supported with FT. To use FT with a virtual machine with this issue, reconfigure the virtual machine without a VMX ROM.
- * N_Port ID Virtualization (NPIV) is not supported with FT. To use FT with a virtual machine with this issue, disable the NPIV configuration of the virtual machine.

Below is some sample output from the SiteSurvey utility showing host and VM compatibility with FT and what features and components are compatible or not:

VMware SiteSurvey Report

Version 1.0

VirtualCenter Server: 172.20.20.37

Generated: Tue May 26 16:48:33 2009

VirtualCenter 172.20.20.37 version 2.5.0 does not support FT

Report for cluster **ESX-01-01-01**

To use FT, resolve the issues marked with **X**

The following ESX hosts are members of the cluster
but have **CPUs that do not support FT**:

ESX-01-01-01	AMD Opteron (tm) Processor 885
ESX-01-01-02	AMD Opteron(tm) Processor 285
ESX-01-01-03	AMD Opteron(tm) Processor 285

Hosts which can work together as an FT cluster
CPU type and processor speed are compatible

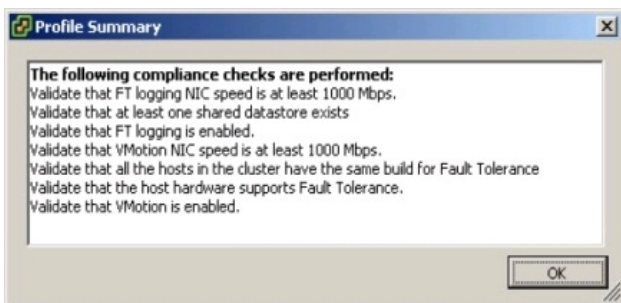
ESX-01-01-01 (AMD CPU, 2300 MHz) :

?	BIOS Compatibility
✓	Compatible CPU steppings
✓	NIC faster than 1 Gb/S
✓	ESX licensed for FT
X	ESX version: 3.5.0 Version must be > 4.0
✓	VMotion NIC
X	Logging NIC
✓	This host has shared storage:

Virtual Machines on **ESX-01-01-01**

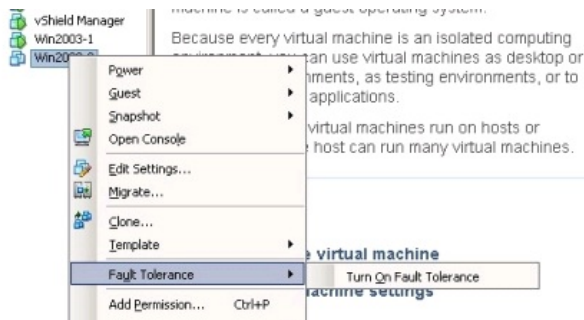
	Storage	CPU	Disk	Snapshots	OS	PRDM	PV	HPIV	Drives	Drivers	HIC
ESX-01-01-01	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ESX-01-01-02	X	✓	?	✓	✓	?	✓	✓	✓	✓	✓
ESX-01-01-03	X	✓	?	✓	✓	?	✓	✓	✓	✓	✓
ESX-01-01-04	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ESX-01-01-05	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ESX-01-01-06	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Another method for checking to see if your hosts meet the FT requirements is to use the vCenter Server Profile Compliance tool. To use this method, select your cluster in the left pane of the vSphere Client, then in the right pane select the Profile Compliance tab. Click the Check Compliance Now link and it will begin checking your hosts for compliance including FT as shown below:



VIII. Are we there yet? Turning on Fault Tolerance

Once you meet the requirements, implementing FT is fairly simple. A prerequisite for enabling FT is that your cluster must have HA enabled. You simply select a VM in your cluster, right-click on it, select Fault Tolerance and then select "Turn On Fault Tolerance."



A secondary VM will then be created on another host. Once it's complete you will see a new Fault Tolerance section on the Summary tab of the VM that will display information including FT status, secondary VM location (host), CPU and memory in use by the secondary VM, the secondary VM lag time (how far behind the primary it is in seconds) and the bandwidth in use for FT logging.



Once you have enabled FT there are alarms available that you can use to check for specific conditions such as FT state, latency, secondary VM status and more.

VIII. Fault Tolerance tips and tricks

Some additional tips and tidbits that will help you understand and implement FT are listed below.

- Before you enable FT be aware of one important limitation, VMware currently recommends that you do not use FT in a cluster that consists of a mix of ESX and ESXi hosts. The reason is that ESX hosts might become incompatible with ESXi hosts for FT purposes after they are patched, even when patched to the same level. This is a result of the patching process and will be resolved in a future release so that compatible ESX and ESXi versions are able to interoperate with FT even though patch numbers do not match exactly. Until this is resolved you will need to take this into consideration if you plan on using FT and make sure you adjust your clusters that will have FT enabled VMs so they only consist of only ESX or ESXi hosts and not both.
- VMware spent a lot of time working with Intel/AMD to refine their physical processors so VMware could implement its vLockstep technology, which replicates non-deterministic transactions between the processors by reproducing the CPU instructions on the other processor. All data is synchronized so there is no loss of data or transactions between the two systems. In the event of a hardware failure you may have an IP packet retransmitted, but there is no interruption in service or data loss as the secondary VM can always reproduce execution of the primary VM up to its last output.
- FT does not use a specific CPU feature but requires specific CPU families to function. vLockstep is more of a software solution that relies on some of the underlying functionality of the processors. The software level records the CPU instructions at the VM level and relies on the processor to do so; it has to be very accurate in terms of timing and VMware needed the processors to be modified by Intel and AMD to ensure complete accuracy. The [SiteSurvey utility](#) simply looks for certain CPU models and families, but not specific CPU features, to determine if a CPU is compatible with FT. In the future, VMware may update its CPU ID utility to also report if a CPU is FT capable.
- Currently there is a restriction that hosts must be running the same build of ESX/ESXi; this is a hard restriction and cannot be avoided. You can use FT between ESX and ESXi as long as they are the same build. Future releases may allow for hosts to have different builds.
- VMotion is supported on FT-enabled VMs, but you cannot VMotion both VMs at the same time. Storage VMotion is not supported on FT-enabled VMs. FT is compatible with Distributed Resource Scheduler (DRS) but will not automatically move the FT-enabled VMs between hosts to ensure reliability. This may change in a future release of FT.
- In the case of a split-brain scenarios (i.e. loss of network connectivity between hosts) the secondary VM may try and become the primary resulting in two primary VMs running at the same time. This is prevented by using a lock on a special FT file; once a failure is detected both VMs will try and rename this file, and if the secondary succeeds it becomes the primary and spawns a new secondary. If the secondary fails because the primary is still running and already has the file locked, the secondary VM is killed and a new

secondary is spawned on another host.

- You can use FT on a vCenter Server running as a VM as long as it is running with a single vCPU.
- There is no limit to the amount of FT-enabled hosts in a cluster, but you cannot have FT-enabled VMs span clusters. A future release may support FT-enabled VMs spanning clusters.
- There is an API for FT that provides the ability to script certain actions like disabling/enabling FT using PowerShell.
- The four FT-enabled VM limit is per host, not per cluster, and is not a hard limit, but is recommended for optimal performance.
- The current version of FT is designed to be used between hosts in the same data center, and is not designed to work over wide area network (WAN) links between data centers due to latency issues and failover complications between sites. Future versions may be engineered to allow for FT usage between external data centers.
- Be aware that the secondary VM can slow down the primary VM if it is not getting enough CPU resources to keep up. This is noticeable by a lag time of several seconds or more. To resolve this try setting a CPU reservation on the primary VM which will also be applied to the secondary VM and will ensure they will run at the same CPU speed. If the secondary VM slows down to the point that it is severely impacting the performance of the primary VM, FT between the two will cease and a new secondary will be found on another host.
- When FT is enabled any memory limits on the primary VM will be removed and a memory reservation will be set equal to the amount of RAM assigned to the VM. You will be unable to change memory limits, shares or reservations on the primary VM while FT is enabled.
- Patching hosts can be tricky when using the FT feature because of the requirement that the hosts must have the build level. There are two methods you can use to accomplish this. The simplest method is to temporarily disable FT on any VMs that are using it, update all the hosts in the cluster to the same build level and then reenabling FT on the VMs. This method requires FT to be disabled for a longer period of time; a workaround if you have four or more hosts in your cluster is to VMotion your FT enabled VMs so they are all on half your ESX hosts. Then update the hosts without the FT VMs so they are the same build levels. Once that is complete disable FT on the VMs, VMotion them to the updated hosts, reenabling FT and a new secondary will be spawned on one of the updated hosts that has the same build level. Once all the FT VMs are moved and reenabled, update the remaining hosts so they are the same build level, and then VMotion the VMs so they are balanced among your hosts.

IX. And there's more! Additional resources

We've provided you with a lot of information on the new FT feature that should help you understand how it works, how to set it up, and how use it. For even more information on FT you can check out the following resources:

VMware White Papers:

- [Protecting Mission-Critical Workloads with VMware Fault Tolerance](#)
- [VMware Fault Tolerance Recommendations and Considerations on VMware vSphere 4](#)

Documentation:

- [Fault Tolerance Home Page](#)
- [Fault Tolerance Datasheet](#)
- [vSphere Availability Guide](#)
- [VMware SiteSurvey FT Configuration Checks](#)

Multimedia:

- [Meet the Engineer - VMware Fault Tolerance](#)
- [Demo of VMware's vSphere Fault Tolerance](#)
- [Fault Tolerance discussion on VMware Communities Roundtable](#)

Utilities

- [VMware SiteSurvey Tool](#)

VMworld sessions:

- [Fault Tolerant VMs in VMware Infrastructure: Operation and Best Practices](#) (VMworld 2008, free registration required)
- [VMware Fault Tolerance Architecture and Performance \(BC2961\)](#) (VMworld 2009, only available to paid attendees or subscribers)
- [VMware Fault Tolerance Real-World Use Cases \(BC3369\)](#) (VMworld 2009, only available to paid attendees or subscribers)
- [VMware Fault Tolerance - Overview and Best Practices \(BC3370\)](#) (VMworld 2009, only available to paid attendees or subscribers)
- [VMware Fault Tolerance - vSphere Workflows and API Considerations \(BC3602 - online session\)](#) (VMworld 2009, only available to paid attendees or subscribers)

Additional Information:

- [VMware Fault Tolerance, single vCPU workloads, and performance on modern hardware](#)
- [VMware engineers caution IT pros: Use Fault Tolerance sparingly](#)

VMware KB Articles:

- [Processors and guest operating systems that support VMware Fault Tolerance \(1008027\)](#)
- [VMware Fault Tolerance FAQ \(1013428\)](#)
- [Understanding VMware Fault Tolerance \(1010601\)](#)
- [VMware Fault tolerance migration transition states \(1010634\)](#)
- [The turn on Fault Tolerance option is disabled \(1010631\)](#)
- [Disabling or Turning Off VMware FT \(1008026\)](#)
- [Reducing FT logging traffic for disk read intensive workloads](#)
- [Do not use both ESX and ESXi hosts in clusters with fault tolerant virtual machines](#)

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great documentation.. really helpful for understanding FT in vSphere, Thanks for sharing such a good post..

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