Virtual Machines for ROC: Initial Impressions

Pete Broadwell

pbwell@cs.berkeley.edu

Talk Outline

1. Virtual Machines & ROC: Common Paths
2. Quick Review of VMware Terminology
3. Case Study: Using VMware for Fault Insertion
4. Future Directions

Background

- Virtual machine: an efficient, isolated duplicate of a real machine – Popek & Goldberg

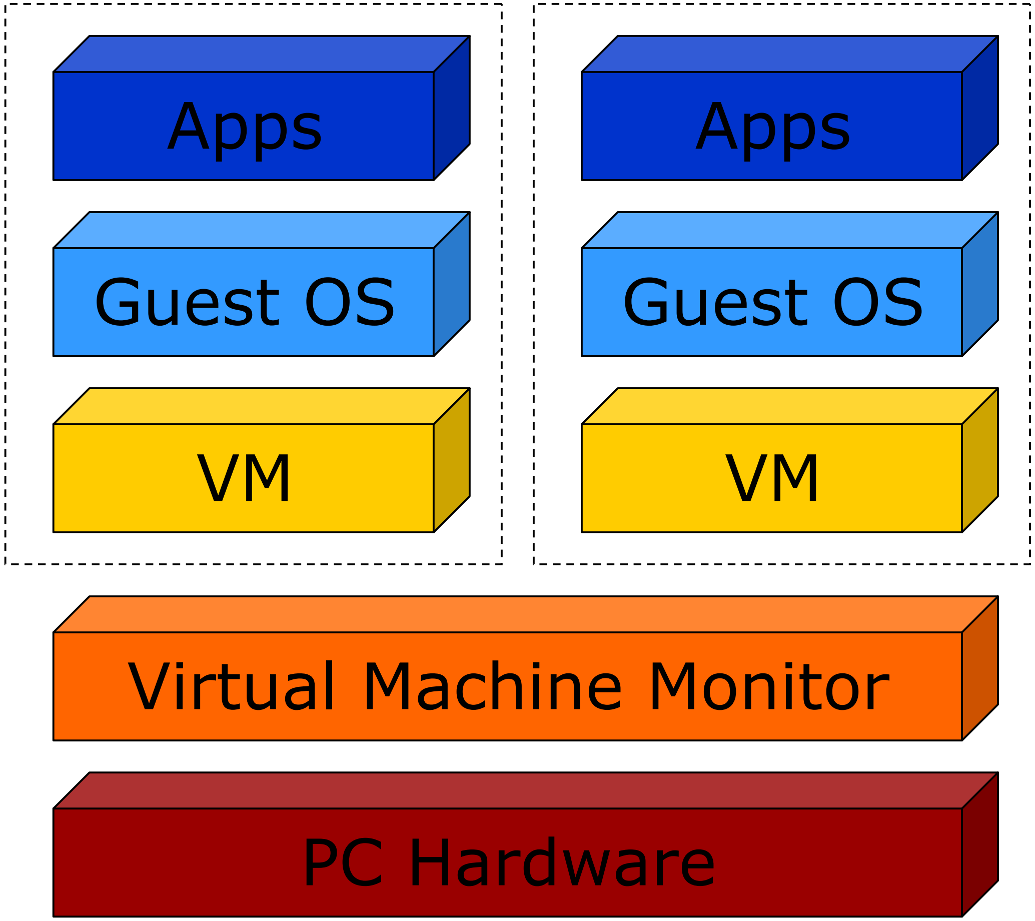
- VMware: an x86-based virtual machine environment
  - Runs on PCs, workstations, servers
  - Supports Linux and Windows
  - Began as a research project at Stanford

ROC & Virtual Machines: A Perfect Match?

Recovery-Oriented Features of VMs

- VM “sandboxing” provides effective **isolation**.
- Multiple VMs on one machine yields **redundancy**.
- Suspend/resume capability means fast failover and **restartability**.
- Support for checkpointing, **undo**able sessions
- Significant support for **monitoring** and **diagnostics**
- **Online verification** of recovery mechanisms?

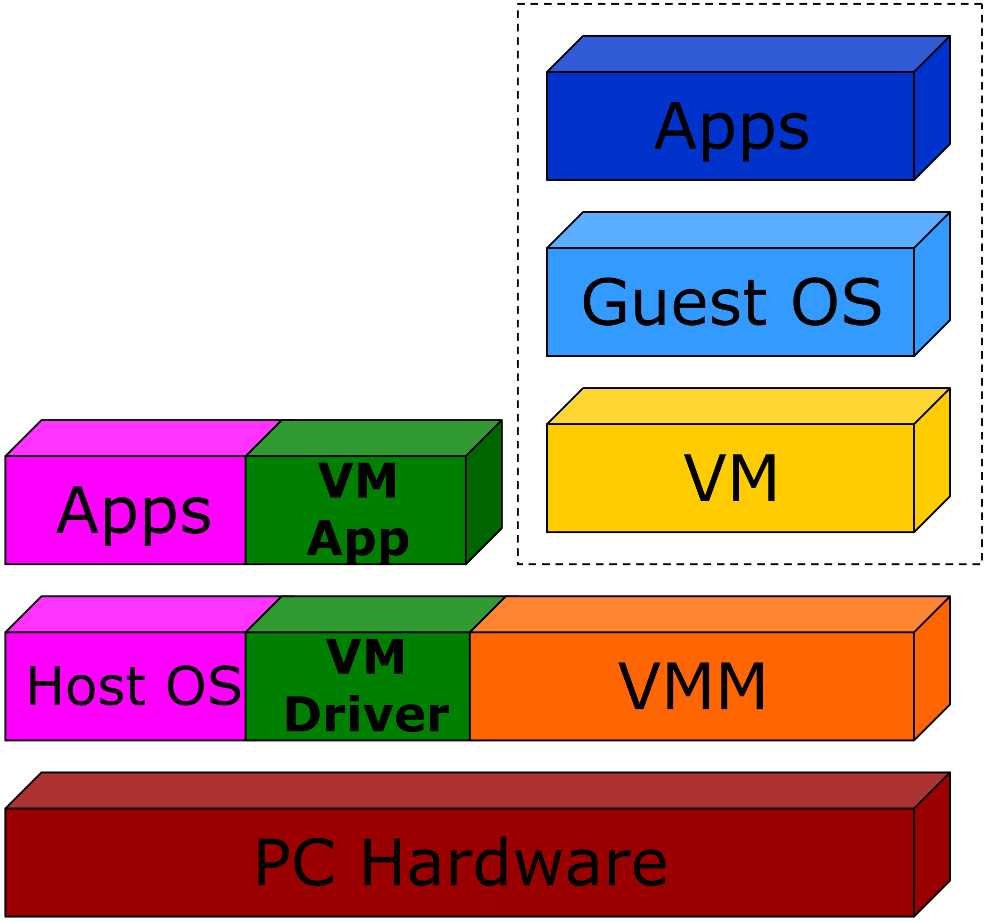
Type I VM: Stand-Alone



- Virtual machine monitor runs on bare hardware, supports multiple virtual machines.

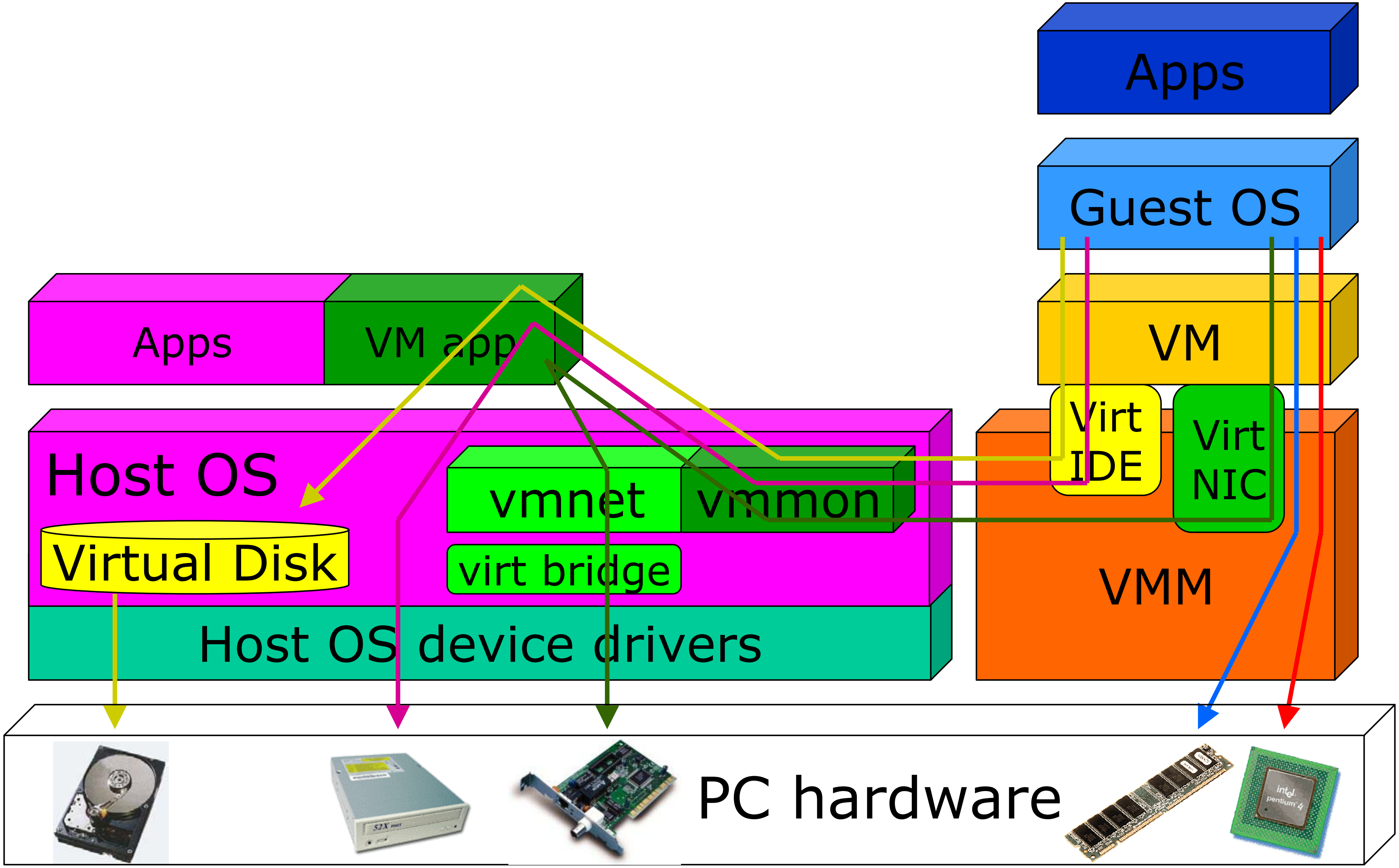
- Examples: VMware ESX Server, IBM z/VM

Type II VM: Hosted

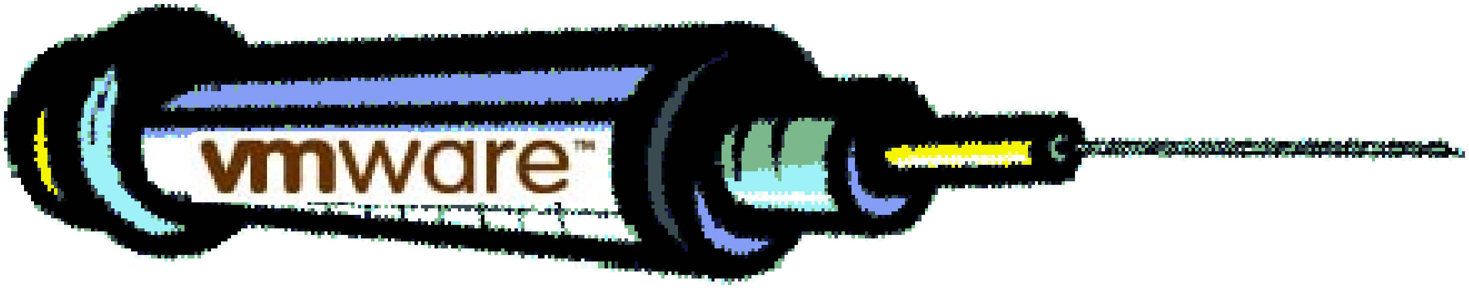


- VM app uses driver to load VMM at privileged level. VMM uses host OS I/O services through VM app.
- Examples: VMware Workstation, VMware GSX Server, Connectix Virtual PC, Plex86

Hosted VM I/O Virtualization



Case Study: Opportunities for Online Fault Injection in VMware GSX Server



Why VMs for Fault Injection?

Fault injection is old news!

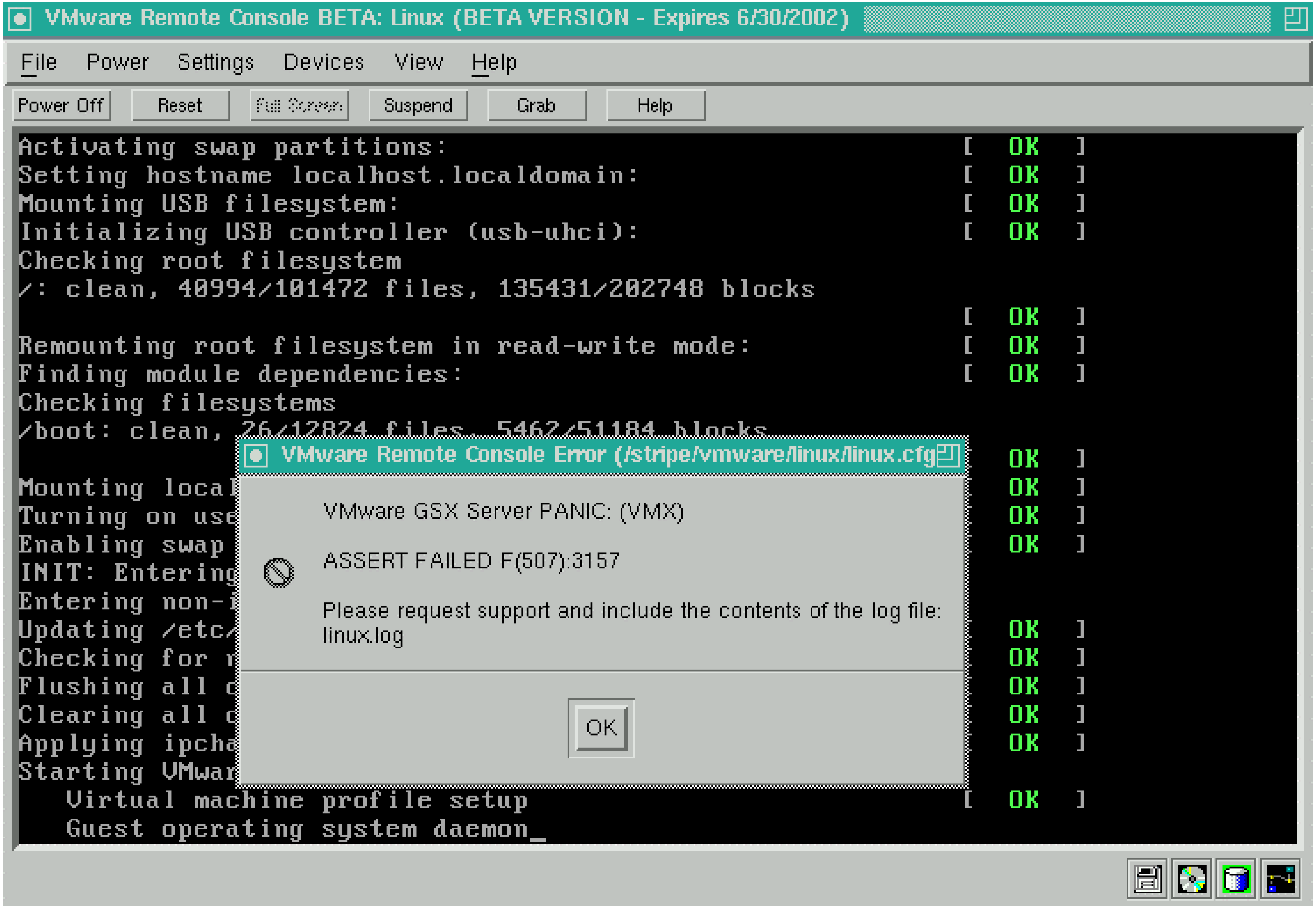
- ROC goals for fault injection:
  - Integrated with operating environment
  - Capable of injecting multiple types
  - Low overhead, high configurability
  - Able to expose latent errors in production systems

Which Faults are Important to Inject?

- Consider errors that have been observed on x86 PCs.

- Of these errors,
  - Which can be inserted using the existing capabilities of VMware?
  - Which require that VMware source code must be modified?
  - Which can’t be injected at all?

VMware does checking of its own!



```
Activating swap partitions:                                     [  OK  ]
Setting hostname localhost.localdomain:                         [  OK  ]
Mounting USB filesystem:                                        [  OK  ]
Initializing USB controller (usb-uhci):                         [  OK  ]
Checking root filesystem
/: clean, 40994/101472 files, 135431/202748 blocks
                                                                [  OK  ]
Remounting root filesystem in read-write mode:                  [  OK  ]
Finding module dependencies:                                    [  OK  ]
Checking filesystems
/boot: clean, 26/12824 files, 5462/51184 blocks
                                                                   OK  ]
Mounting local                                                     OK  ]
Turning on use                                                     OK  ]
Enabling swap                                                      OK  ]
INIT: Entering                                                     OK  ]
Entering non-i
Updating /etc/                                                     OK  ]
Checking for r                                                     OK  ]
Flushing all c                                                     OK  ]
Clearing all c                                                     OK  ]
Applying ipcha                                                     OK  ]
Starting VMwar
   Virtual machine profile setup                                [  OK  ]
   Guest operating system daemon_
```

VMware Remote Console Error (/stripe/vmware/linux/linux.cfg

VMware GSX Server PANIC: (VMX)

ASSERT FAILED F(507):3157

Please request support and include the contents of the log file: linux.log

Memory/Processor Errors

- Want to simulate processor faults, memory ECC errors.
- Problem: in VMware, processor ops & memory accesses execute directly on hardware (not simulated).
- Need to allow VM to return “machine check” exception to guest OS.

Not difficult to guess what will happen:
kernel panic or blue screen.

Memory Corruption

- VMs use file system as backing for pinned memory pages – point for inserting corruption errors.
- VM driver (open source) interposes upon memory requests between VMs & host OS – can insert memory errors here.

Easy to do, but not very interesting or realistic.

Disk Fault Injection

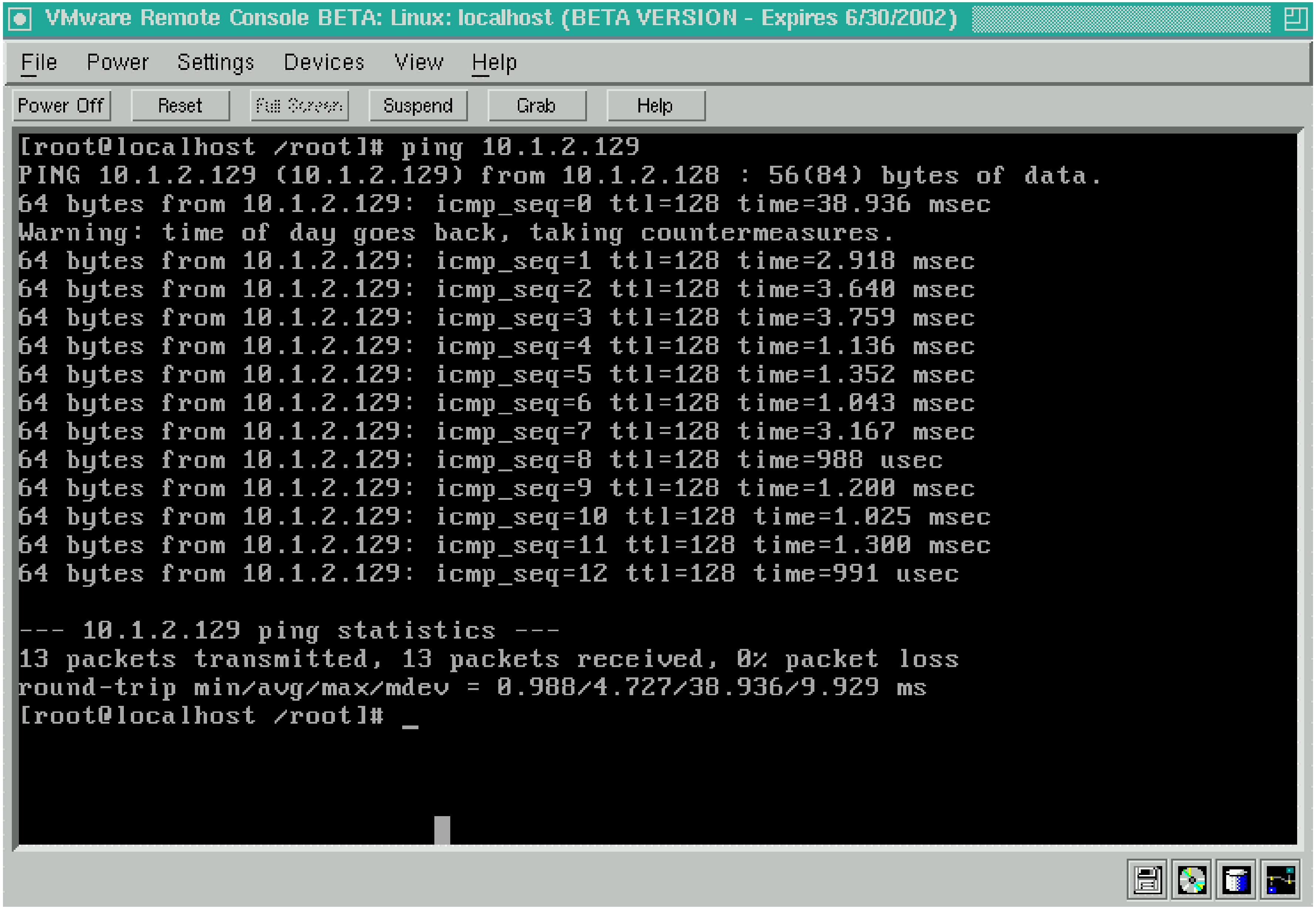
- By default, a VM’s virtual disk image is a flat file.
- Failures: catch read/write calls to the file, return errors indicating bad blocks, device failures to OS.
- Transient failures: overwrite random portions of disk image.

Should be relatively straightforward.

Network Device Faults

- VMware’s virtual network module is open-source.
- Modify module, introduce failure code at virtual bridges and hubs
  - Drop packets
  - Corrupt packets
  - Simulate slowdown
  - Simulate DOS attacks

Virtual Hub: No Faults

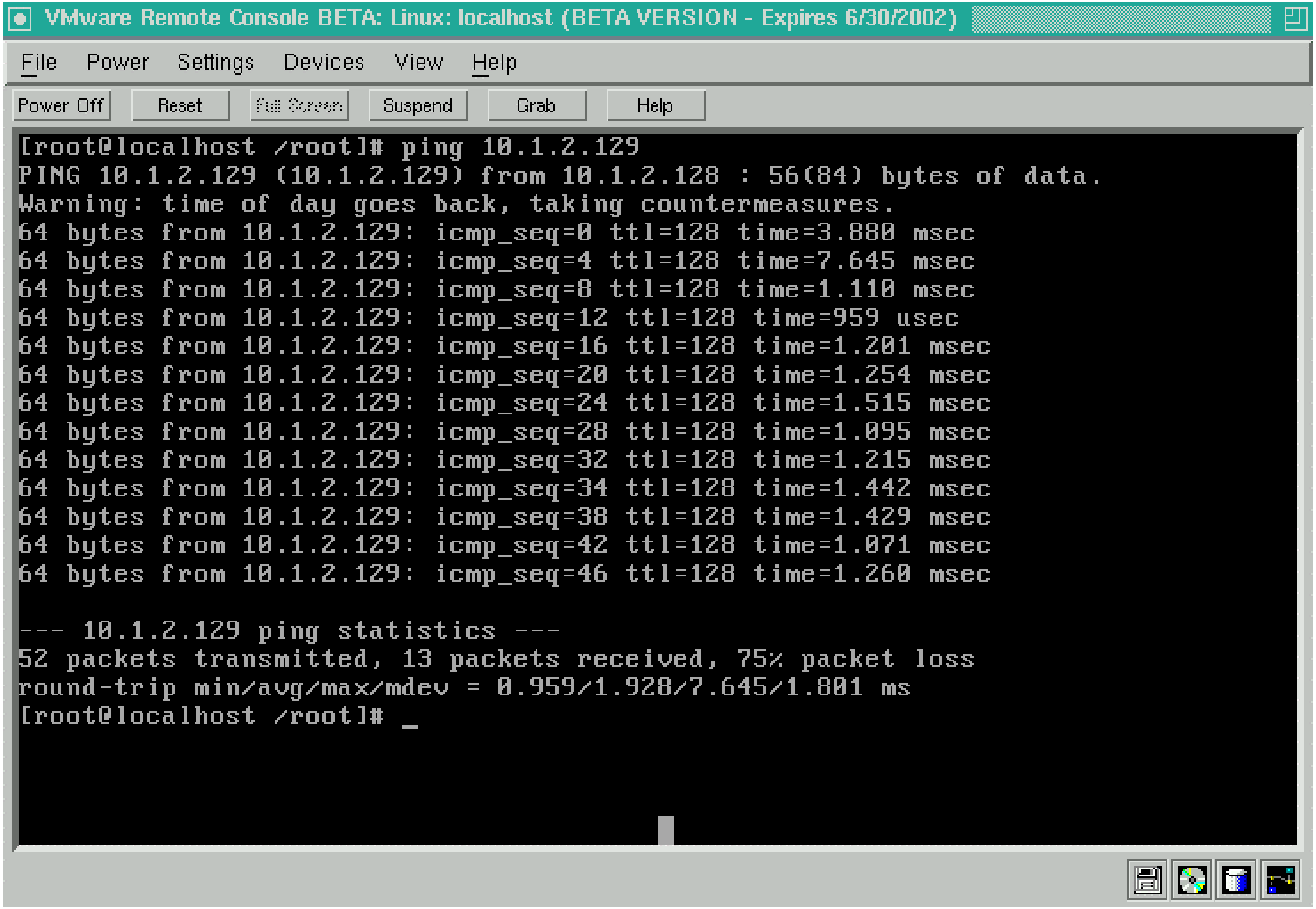


VMware Remote Console BETA: Linux: localhost (BETA VERSION - Expires 6/30/2002)
File
Power
Settings
Devices
View
Help
Power Off
Reset
Full Screen
Suspend
Grab
Help

```
[root@localhost /root]# ping 10.1.2.129
PING 10.1.2.129 (10.1.2.129) from 10.1.2.128 : 56(84) bytes of data.
64 bytes from 10.1.2.129: icmp_seq=0 ttl=128 time=38.936 msec
Warning: time of day goes back, taking countermeasures.
64 bytes from 10.1.2.129: icmp_seq=1 ttl=128 time=2.918 msec
64 bytes from 10.1.2.129: icmp_seq=2 ttl=128 time=3.640 msec
64 bytes from 10.1.2.129: icmp_seq=3 ttl=128 time=3.759 msec
64 bytes from 10.1.2.129: icmp_seq=4 ttl=128 time=1.136 msec
64 bytes from 10.1.2.129: icmp_seq=5 ttl=128 time=1.352 msec
64 bytes from 10.1.2.129: icmp_seq=6 ttl=128 time=1.043 msec
64 bytes from 10.1.2.129: icmp_seq=7 ttl=128 time=3.167 msec
64 bytes from 10.1.2.129: icmp_seq=8 ttl=128 time=988 usec
64 bytes from 10.1.2.129: icmp_seq=9 ttl=128 time=1.200 msec
64 bytes from 10.1.2.129: icmp_seq=10 ttl=128 time=1.025 msec
64 bytes from 10.1.2.129: icmp_seq=11 ttl=128 time=1.300 msec
64 bytes from 10.1.2.129: icmp_seq=12 ttl=128 time=991 usec

--- 10.1.2.129 ping statistics ---
13 packets transmitted, 13 packets received, 0% packet loss
round-trip min/avg/max/mdev = 0.988/4.727/38.936/9.929 ms
[root@localhost /root]# _
```

Virtual Hub: Injected Faults


VMware Remote Console BETA: Linux: localhost (BETA VERSION - Expires 6/30/2002)
File
Power
Settings
Devices
View
Help
Power Off
Reset
Full Screen
Suspend
Grab
Help

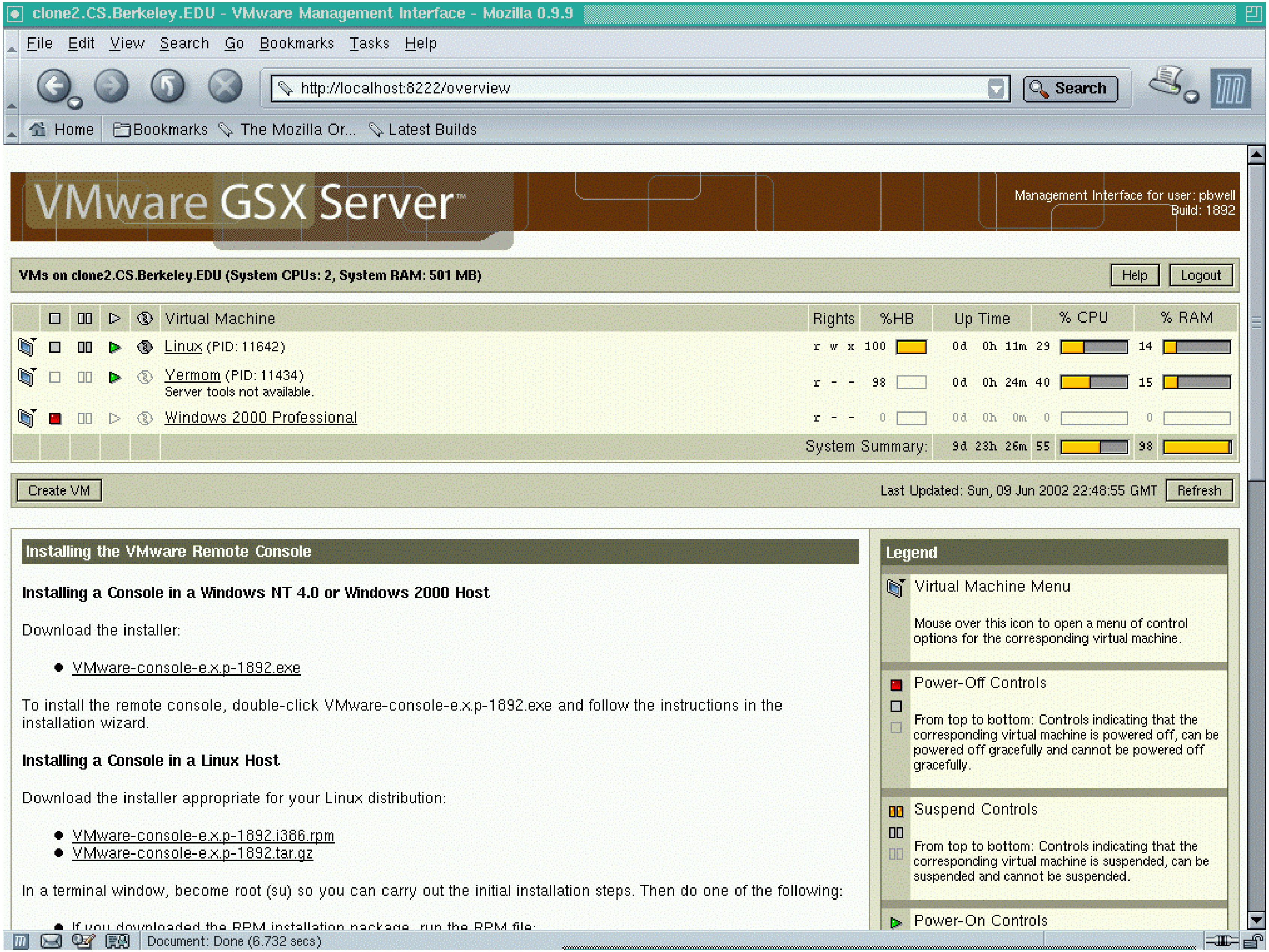
```
[root@localhost /root]# ping 10.1.2.129
PING 10.1.2.129 (10.1.2.129) from 10.1.2.128 : 56(84) bytes of data.
Warning: time of day goes back, taking countermeasures.
64 bytes from 10.1.2.129: icmp_seq=0 ttl=128 time=3.880 msec
64 bytes from 10.1.2.129: icmp_seq=4 ttl=128 time=7.645 msec
64 bytes from 10.1.2.129: icmp_seq=8 ttl=128 time=1.110 msec
64 bytes from 10.1.2.129: icmp_seq=12 ttl=128 time=959 usec
64 bytes from 10.1.2.129: icmp_seq=16 ttl=128 time=1.201 msec
64 bytes from 10.1.2.129: icmp_seq=20 ttl=128 time=1.254 msec
64 bytes from 10.1.2.129: icmp_seq=24 ttl=128 time=1.515 msec
64 bytes from 10.1.2.129: icmp_seq=28 ttl=128 time=1.095 msec
64 bytes from 10.1.2.129: icmp_seq=32 ttl=128 time=1.215 msec
64 bytes from 10.1.2.129: icmp_seq=34 ttl=128 time=1.442 msec
64 bytes from 10.1.2.129: icmp_seq=38 ttl=128 time=1.429 msec
64 bytes from 10.1.2.129: icmp_seq=42 ttl=128 time=1.071 msec
64 bytes from 10.1.2.129: icmp_seq=46 ttl=128 time=1.260 msec

--- 10.1.2.129 ping statistics ---
52 packets transmitted, 13 packets received, 75% packet loss
round-trip min/avg/max/mdev = 0.959/1.928/7.645/1.801 ms
[root@localhost /root]# _
```

Cluster-Level Faults

- Use VMware’s built-in remote management interface to hard-suspend nodes in a cluster, remove network bridges.
- Verify recovery/failover routines in cluster management software.
  - Dell Scalable Enterprise Computing
  - MS Cluster Server
  - NetWare Cluster Services
  - Microsoft SQL Server!

(Virtual) Cluster Management Interface



clone2.CS.Berkeley.EDU - VMware Management Interface - Mozilla 0.9.9
File Edit View Search Go Bookmarks Tasks Help
http://localhost:8222/overview
Search
Home
Bookmarks
The Mozilla Or...
Latest Builds
VMware GSX Server™

Management Interface for user: pbwell
Build: 1892

VMs on clone2.CS.Berkeley.EDU (System CPUs: 2, System RAM: 501 MB)

	□	▯▯	▷	◎	Virtual Machine	Rights	%HB		Up Time	% CPU		% RAM	
	□	▯▯	▶	◎	Linux (PID: 11642)	r w x	100		0d 0h 11m	29		14	
	□	▯▯	▶	◎	Yermom (PID: 11434) Server tools not available.	r - -	98		0d 0h 24m	40		15	
	■	▯▯	▷	◎	Windows 2000 Professional	r - -	0		0d 0h 0m	0		0	
						System Summary:			9d 23h 26m	55		98	

Last Updated: Sun, 09 Jun 2002 22:48:55 GMT

Installing the VMware Remote Console

Installing a Console in a Windows NT 4.0 or Windows 2000 Host

Download the installer:

- VMware-console-e.x.p-1892.exe

To install the remote console, double-click VMware-console-e.x.p-1892.exe and follow the instructions in the installation wizard.

Installing a Console in a Linux Host

Download the installer appropriate for your Linux distribution:

- VMware-console-e.x.p-1892.i386.rpm
- VMware-console-e.x.p-1892.tar.gz

In a terminal window, become root (su) so you can carry out the initial installation steps. Then do one of the following:

- If you downloaded the RPM installation package, run the RPM file:

Legend

Virtual Machine Menu

Mouse over this icon to open a menu of control options for the corresponding virtual machine.

■ □ □ Power-Off Controls

From top to bottom: Controls indicating that the corresponding virtual machine is powered off, can be powered off gracefully and cannot be powered off gracefully.

▯▯ ▯▯ ▯▯ Suspend Controls

From top to bottom: Controls indicating that the corresponding virtual machine is suspended, can be suspended and cannot be suspended.

▶ Power-On Controls

Document: Done (6.732 secs)

Analysis

- Levels of difficulty for different fault injection types:
  - CPU, cache, & memory (non-corruption) are hard to do.
  - Memory corruption, disk, NIC, peripherals may be medium.
  - Network, cluster level is easy.

The Big Picture

- Want to develop models for multiple correlated faults & implement them.
- Combine fault injection with introspection tools for anomaly detection & root-cause analysis.