Virtual Machines

- Allow you to run a Guest Operating System on top of a Host Operating System
  - VMware (for most systems)
  - Microsoft Virtual PC, Virtual Server
  - Parallels (for Mac OS X)
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Virtual Machine Usage

- Run applications written for another OS
  - Convenience for a Desktop / Laptop system
  - Efficient hw usage for servers
- Windows 7 includes a virtual machine to provide Windows XP compatibility
Virtual Machine Usage

- Simplifies Regression (Repeated) Testing of applications
  - Simply restart a saved virtual configuration to repeat a test
- Have one machine that can be used to test applications for different OSs
Virtual Machine Usage

- By having Virtual Machine configuration on a server ...
  - Can tremendously simplify deployment to desktops when all desktops are same
  - Example. Call Center
Virtual Machine

<table>
<thead>
<tr>
<th>Host Application</th>
<th>Guest Application</th>
<th>Host Kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Call Interface</td>
<td>Guest OS</td>
<td>Hardware</td>
</tr>
<tr>
<td>Virtual Machine Interface</td>
<td>Guest Application</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Guest OS 2</td>
<td></td>
</tr>
</tbody>
</table>
Virtual Machine Requirements

- **Fidelity**
  - Programs run same on virtual machine as a real computer

- **Performance**
  - Programs should run at close to the same speed on the virtual machine

- **Safety**
  - Programs running on virtual machine must be unable to interfere with Host OS or other apps
Virtual Machine Requirements

- Guest Application and Guest OS must execute same whether on virtual machine or real hardware
  - Regular instructions
  - Privileged instructions
  - Sensitive instructions
    - Instructions that act differently depending on whether computer is in OS or User Mode
Virtual Machine Requirements

- Execution of Guest Machine Instructions
  - Can be done if Host & Guest have different machine instructions, but is slow
  - Best if Host & Guest are for same CPU
- Proper handling of Guest OS execution of privileged & sensitive instructions
  - Typically requires interpretation of intent of the instruction
  - Can be difficult & cumbersome
System Call Handling
System Call Handling with Hardware support
Input / Output
Input / Output with hardware support
# Device Mapping

<table>
<thead>
<tr>
<th>Guest OS</th>
<th>Host OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen</td>
<td>Application Window</td>
</tr>
<tr>
<td>Main Disk</td>
<td>File</td>
</tr>
<tr>
<td>Network Card</td>
<td>Virtual Network Port</td>
</tr>
</tbody>
</table>
Efficient Device Mapping

- A custom Guest OS device driver is installed for each mapped device
  - Avoids complex interpretation of privileged instructions
  - Increases efficiency
Non-Mapped Devices

- CD, USB devices
- Virtual Machine must obtain exclusive control over these devices to avoid conflicts with applications running on other operating systems (including the Host OS)
Memory Mapping

- Requires Host OS to interpret Guest OS’s attempts to set values into page tables.
- Hardware support for virtual (extended) page tables minimizes this.
Memory Mapping
Integrating Guest & Host

- Makes entire system look more like one computer rather than 2 separate entities
## Integrating Guest & Host

<table>
<thead>
<tr>
<th>Host OS</th>
<th>Guest OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>File System</td>
<td>Network Drive</td>
</tr>
<tr>
<td>Clipboard</td>
<td>Clipboard</td>
</tr>
<tr>
<td>Application Window</td>
<td>Application Window</td>
</tr>
</tbody>
</table>
Integrate Host File System

- Can be mapped as a Network Drive on the Guest
- Configurable Feature
  - Allows Guest OS/Apps to share files with other OSs (including Host)
  - Not configuring this isolates Guest system for security purposes
Integrated Clipboard

- Allows cut & paste between applications running on different operating systems
Integrated Windows

- Instead of mapping Guest Application window onto a Host window for the Guest OS …
- Guest Application window goes to Host Application window
  - Makes Guest Application appear as though it is running on the Host