Virtualization and Abstractions

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Operating Systems: A Great Illusionist

★ So far, the Operating System has done an amazing job:
  ○ As a process, it appears that we have ________________.
  ○ ...and has ________________________________!

★ Do we really need more abstraction??
Big Idea: The OS is an illusionist

Hardware Platform Virtualization
Running hardware platform-specific binaries on different hardware.

Operating System Virtualization
Running guest operating systems within a host operating system environment (VirtualBox)

Hardware Virtualization
Mobile development is full of hardware virtualization to test mobile apps in various environments.
Virtualization

★ The goal of all virtualization is to map a ________________ onto a ____________:
Virtualization

★ The goal of all virtualization is to map a virtual machine onto a host machine:

○ All virtual states $S_x$ can be represented on the host system as $H(S_x)$.

○ For all sequence of translations between $S_1 \Rightarrow S_2$, there’s a sequence of operations that map $H(S_1) \Rightarrow H(S_2)$.
A Virtual “Machine”

★ A “machine” is:
A Virtual “Machine”

★ A “machine” is: any entity that provides an interface:

○ Language Virtualization

○ Process Virtualization

○ System Virtualization
A Virtual “Machine”

★ A “machine” is: any entity that provides an interface:

- **Language Virtualization**
  - Machine := Entity that provides the API

- **Process Virtualization**
  - Machine := Entity that provides the ABI

- **System Virtualization**
  - Machine := Entity that provides the ISA
Language Virtualization
Language Virtualization Example

<table>
<thead>
<tr>
<th>Initial State (S₁):</th>
<th>Transition (S₁ ⇒ S₂):</th>
<th>Final State (S₂):</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System #1</strong></td>
<td><strong>System #2</strong></td>
<td><strong>System #3</strong></td>
</tr>
<tr>
<td>COPY r1 1</td>
<td>COPY r1 x</td>
<td>COPY r1 x</td>
</tr>
<tr>
<td>SHIFTL x 2</td>
<td>SHIFTL x</td>
<td>ADD r1 x</td>
</tr>
<tr>
<td>ADD x r1</td>
<td>ADD x r1</td>
<td>ADD r1 x</td>
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<td>ADD r1 x</td>
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</table>
Process Virtualization
### Process Virtualization Example

<table>
<thead>
<tr>
<th>Initial State ($S_1$):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition ($S_1 \Rightarrow S_2$):</td>
</tr>
<tr>
<td>Final State ($S_2$):</td>
</tr>
</tbody>
</table>
System VMs

★ Type 1 Hypervisor
System VMs

★ Type 1 Hypervisor
  ○ Implement **on bare hardware**
  ○ Most efficient,
  ○ Must support hardware emulation (drivers), and
  ○ Replaces any OS hosted on the bare hardware.
System VMs

★ Type 2 Hypervisor
System VMs

★ Type 2 Hypervisor
  ○ Implement a VMM **on top of a host OS:**
    ○ Less efficient,
    ○ Leverages the OS drivers and hardware abstractions, and
    ○ Easy to install on top of the host OS.
System VMs

How has this changed our industry?
Infrastructure as a Service (IaaS)
Containers as a Service (CaaS)

Containers provide an __________________________ of a system that can be deployed in an isolated environment on heterogeneous systems.

Key Technology:
Docker Containers

Container Developer:

Container User:
FROM gcc:latest
COPY ./docker/entrypoint.sh /
RUN chmod +x entrypoint.sh
ENTRYPOINT ["/entrypoint.sh"]

docker build --tag mp3-docker .
docker run -it --rm -v "pwd":/mp3 mp3-docker "make"

docker run --rm -it -p 27017:27017 mongo