Unshackle the Cloud!

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IaaS Clouds Offer Diverse Features

- Popular IaaS clouds are becoming **feature-rich**
  - Integrated monitoring
  - VM migration
  - CPU bursting

- **Hypervisor-level** innovations are emerging
  - Availability (e.g. Remus [Cully et al., NSDI 2008])
  - Security (e.g. Revirt [Dunlap et al., OSDI 2002])
  - Efficiency (e.g. Overdriver [Williams et al., VEE 2011])
Users Don't Control Features

- Large cloud users with 100's or 1000's of VMs need control
- Must rely on provider to expose hypervisor-level features
- Tools and features lead to lock-in

- **Users can't implement hypervisor-level features themselves**
Unshackle the Cloud with Extensible Clouds: xClouds

- Bring **extensibility** into IaaS clouds
- Allow users to run or implement **their own hypervisor-level services**
- Avoid lock-in with **user-centric homogenization**
How to Build xClouds

- Users are isolated
- VMM composed of modules
How to Build xClouds

- Users are isolated
- VMM composed of modules
  - User / Provider
    ( U / P )

![Diagram showing VMs and users]

Hardware
How to Build xClouds

• Users are isolated
• VMM composed of **modules**
  • User / Provider  
    ( U / P )
  • Mutable / Immutable  
    ( U / P )
How to Build xClouds

• Users are isolated
• VMM composed of modules
  • User / Provider
    (U / P)
  • Mutable / Immutable
    (U / P)
• Some modules access hardware
Download VMM Extensions

e.g. SPIN, VINO

Providers must adopt new VMM

Hardware
## Design Alternatives

<table>
<thead>
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![Diagram showing software and hardware interactions](image-url)
# Design Alternatives

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![Diagram showing three alternatives](image_url)
Nested Virtualization can be Deployed Today!

- Use PV or BT for user-controlled VMM
- No provider cooperation necessary

![Diagram showing Nested Virtualization]

- User-Controlled VMM (e.g. Xen)
- Provider-Controlled VMM (e.g. Amazon EC2)
Evaluation: Will xClouds Perform?

- Compared single and nested setups with Xen (PV) as the second-layer hypervisor
- Microbenchmarks
  - Nested perf. comparable to single-layer PV
Evaluation: Will xClouds Perform?

- Compared single and nested setups with Xen (PV) as the second-layer hypervisor
- Microbenchmarks
  - Nested perf. comparable to single-layer PV
- Device I/O benchmarks
  - Xen is not designed to run on PV hardware
  - Nested PV is essential for device I/O

![Network Receive Throughput](image)
xClouds Work Today!

- Nested paravirtual device drivers
- Xen on EC2 HVM instance
- Ongoing work
“Nature is a mutable cloud which is always and never the same”

– Ralph Waldo Emerson

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