What is the right balance for performance and isolation with virtualization in HPC?

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Overview

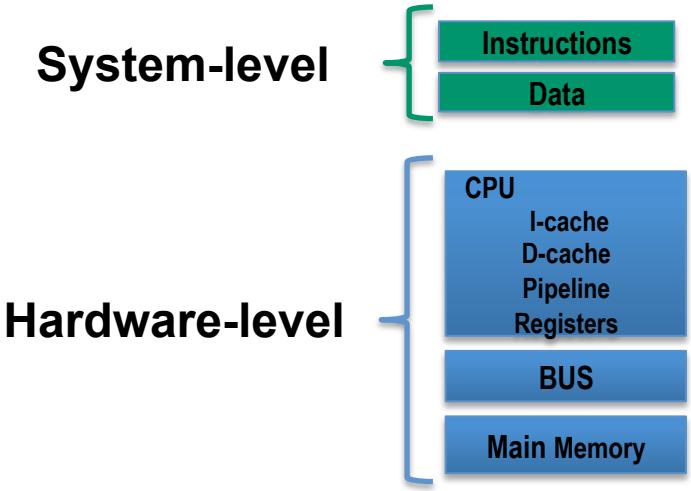
- HPC facing new challenges due to growing scale & complexity
  - Scalable algorithms
  - Fault tolerance
- HPC system software must balance
  - Performance / Usability / Robustness
  - System-level virtualization gaining attention in recent years
- Benefits of virtualization for HPC
  - User-customizable execution environment
  - Increased functionality
    - Specialized Micro-kernels vs. General Purpose kernels

Motivating High-level Questions

- What are the right policies and expectations for failures when using virtualization in HPC?
- How do performance & protection tradeoffs factor into resilience policies?
- How can we better organize the view of the platform to aid resilience policy choices?

Error Models

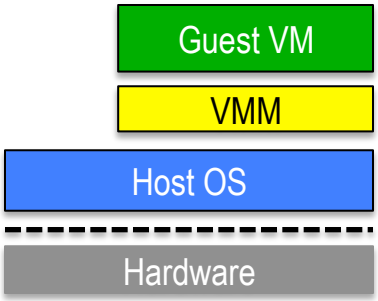
- HPC Resilience focused on gracefully coping with errors
  - Fault ➔ Error ➔ Failure
- Error model
  - Provides abstraction to aid reasoning about behavior
- Hardware/System model
  - Goloubeva et al. offer good description
  - Hardware errors manifest as system errors
    - i.e., errors in instructions or data



O. Goloubeva, M. Rebaudeng, M. S. Reorda, and M. Violante, Software-Implemented Hardware Fault Tolerance. Springer, 2006.

Error Models & Virtualization

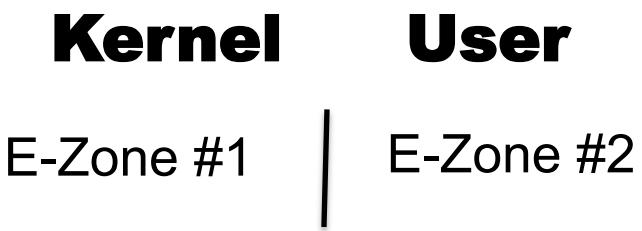
- Error models for HPC virtualization
  - VMs offer additional layer of indirection from hardware
    - Guest VM instructions & data
  - Help reason about behavior in this context
  - Aid study of performance / isolation problem



- Virtualization
  - VMs offer ability to increase isolation / protection (tradeoffs)

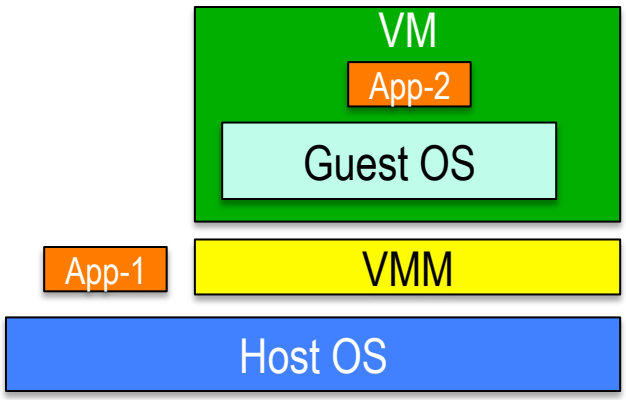
Error Zones

- "*Error zones*" are regions where faults may occur in the system
- Standard separation for protection has two zones
  - User-space
  - Kernel-space
- Control effects (scope) of failures
  - System crashes (global effects)
  - Process crashes (limited effects)



Error Zones

- New error zones for virtualized regions
  - Distinguish “Host” and “Guest” areas
- Additional regions offer more zones to control for failures



	Kernel	User
Host	E-Zone #1	E-Zone #2
Guest	E-Zone #3	E-Zone #4

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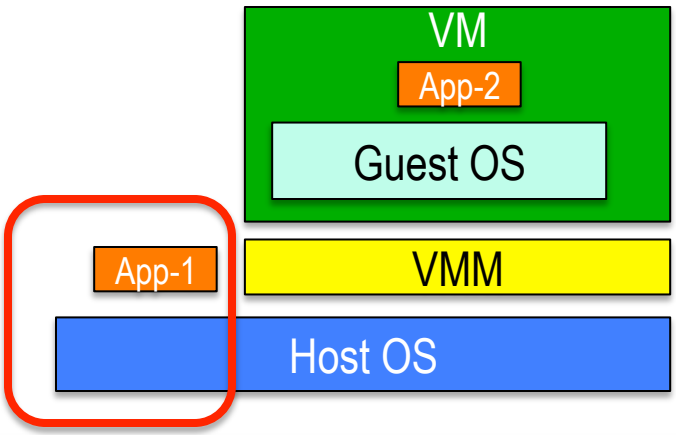

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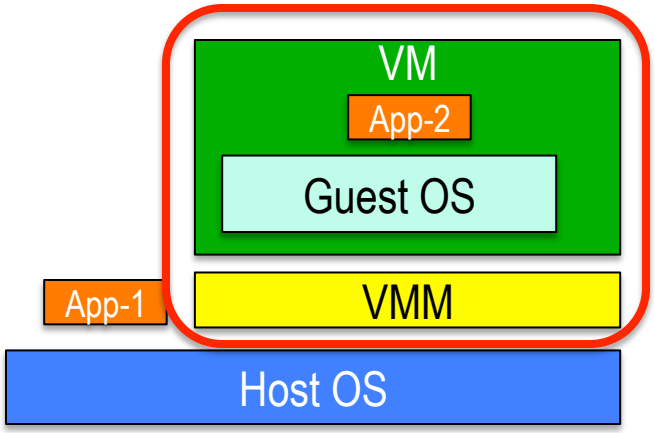

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Error model for virtualization-enabled context

A. Errors may crash full system (global effects)

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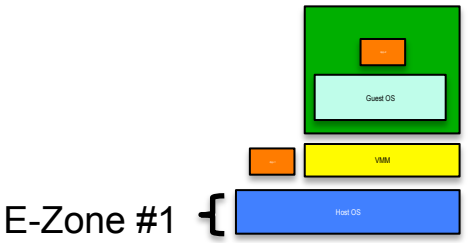

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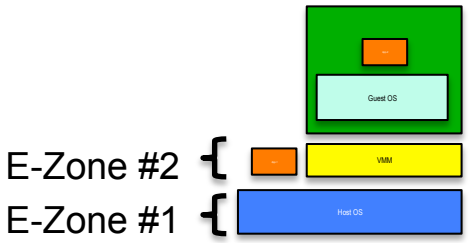

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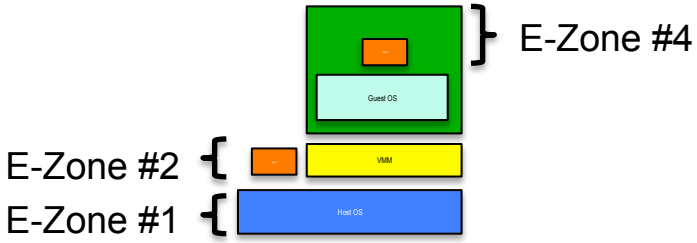

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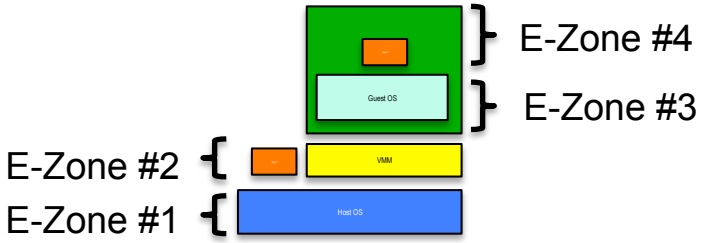

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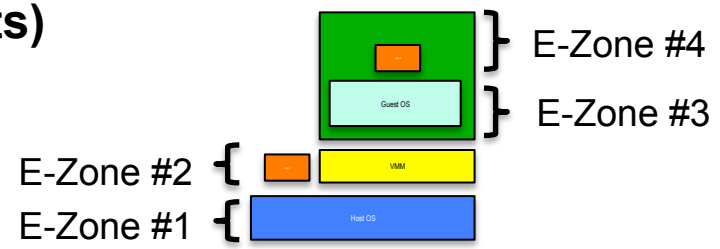

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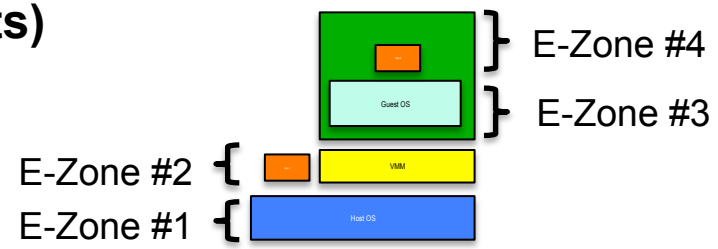
C. Errors may be managed in mixed manner (varied effects)



Guest OS Errors

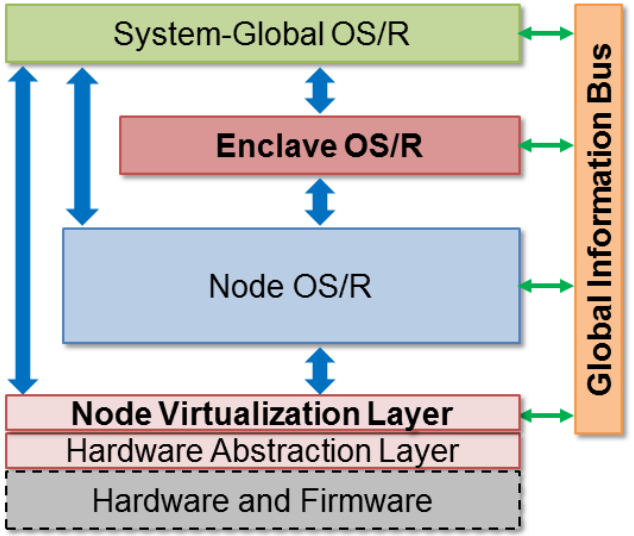
- What is proper dispositions for Error-Zone#3 ?
  - Example: Priority on protection, then E-Zone#3 ≈ E-Zone#2
  - Example: Priority on performance, then E-Zone#3 ≈ E-Zone#1

	Kernel	User
Host	E-Zone #1	E-Zone #2
Guest	E-Zone #3	E-Zone #4

- Consider this question in context of Hobbes OS/R project

Hobbes – Extreme Scale OS/Runtime

- Brief Synopsis
  - U.S. DOE project
    - Nat'l labs & universities
  - Design OS/Runtime interfaces for next generation machines
  - Two distinguishing elements
    - Enclaves & Composition
- Enclaves
  - Partition of the system allocated to a single application or service
  - Virtualization used to implement partitioning and isolation
- Composition
  - Joining applications/services to form more advanced instances
  - Mechanisms to relax isolation between enclaves to facilitate sharing between applications (in enclaves)



http://xstack.sandia.gov/hobbes

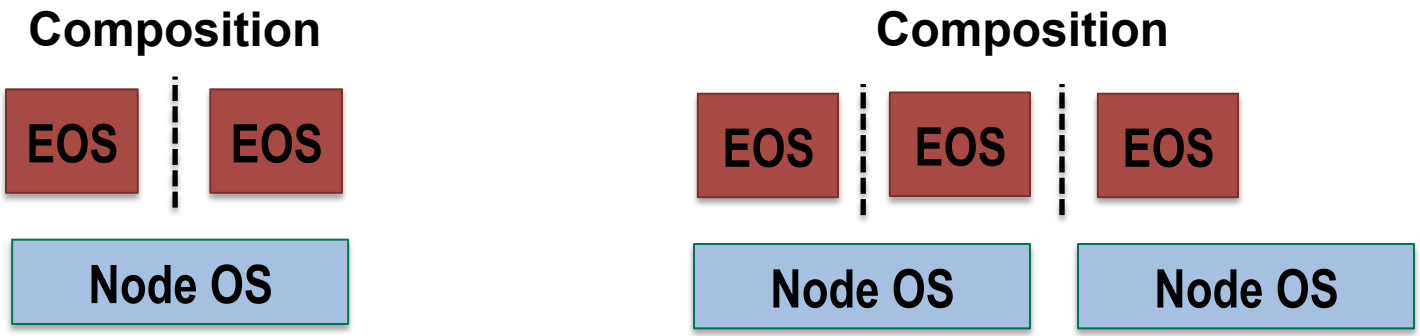
Considering E-Zones in Hobbes Context

- Important step in Hobbes resilience effort
  - Refine error models
  - Consider the two distinguishing elements from *Hobbes*
    - Enclaves & Composition
- What should be the E-Zone#3 policies for error management?
  - Will influence performance / isolation decisions
- One motivation for virtualization
  - Increased functionality (run a full feature OS as guest OS in E-Zone#3)
    - Could assume: E-Zone#1 == E-Zone#3

Considering E-Zones in Hobbes Context (2)

- Composing different enclaves may be less straightforward
  - Crashing 1 enclave (VM) may be ok
  - Crashing multiple enclaves (VMs) may be un-acceptable
    - Add protections to limit cross-enclave interactions

- Example with few Enclave OS (EOS) instances



Thoughts on Resilience in Hobbes

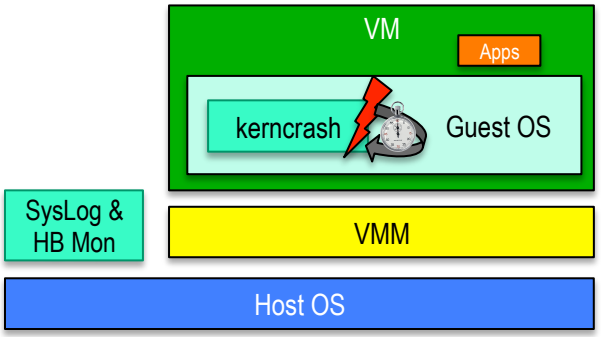
- Error-Zone disposition should be factored into enclave setup
  - Possibly offer ability to tailor degree of protection in enclave interfaces
  - Possibly have Node OS dictate allowable degree of protection when setting up enclaves
  - Possibly avoid protection if low/no composition
    - Maybe defer until composition is requested
- Need isolation tests
  - Develop hooks into interfaces & tests for probing
  - Offer ability to perform fault-injection & robustness testing

Evaluation: Error-Zone#3 Tests

- Considered three virtualization systems
  - QEMU – entirely user-space
  - KVM – kernel module (general purpose focused)
  - Palacios – kernel module (HPC focused)

- Synthetic guest kernel error (E-Zone#3)
  - QEMU & KVM isolated
    - E-Zone#3 had limited effects, crash is contained
  - Palacios isolated
    - E-Zone#3 had some host effects

    (*possible bug: shared host/vmm networking*)



Summary

- HPC system software
  - Tradeoffs between Performance / Usability / Robustness
  - Leverage virtualization for user-customization & added functionality
- Error models in context of HPC virtualization
  - Classified into "**Error Zones**"
  - Provides abstraction to help reason about expected behavior
- Performance & isolation in HPC resilience
  - Analysis of performance / isolation using error-zones
  - Impact on resilience strategies in context of *Hobbes* project
  - Experiments to demonstrate effects of synthetic errors

Thank you & enjoy the conference

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