Secure Enclaves: An Isolation-centric Approach for Creating Secure High Performance Computing Environments

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Challenges

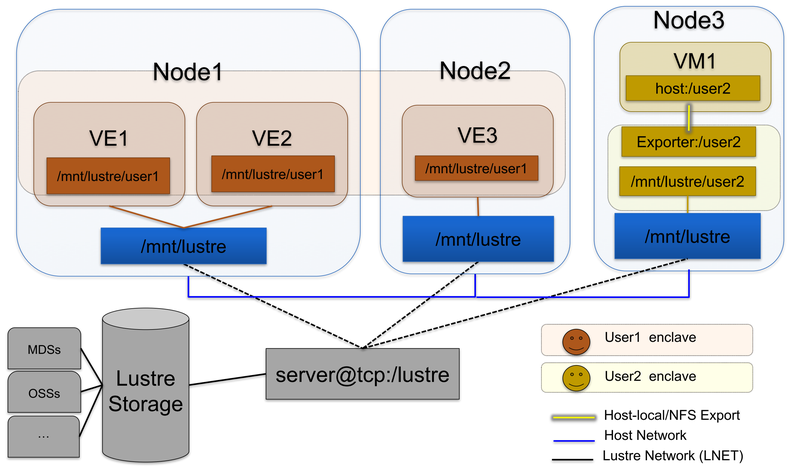
- **HPC environments process variety of workloads**
  - May process data at various levels of security
  - Often forced to enclave at highest security posture
- **Controlling access to shared HPC resources**
  - Gaps in security/protection mechanisms for HPC services
  - Must retain "P" (performance) for HPC workloads
- **Create configurable and secure enclaves**
  - Customizable to support different users
  - Properly isolated for multi-tenant environment

Project Overview

- **Compute: Use different methods of virtualization**
  - Hypervisor-based vs. Containers-based virtualization
  - Virtual Machine (VM): Customize guest kernel/system
  - Virtual Environment (VE): Customize system stack (above kernel)
- **Network: Create per-tenant enclaves**
  - Software Defined Networking (SDN) for on-demand enclaving
- **Storage: Marshal parallel file-system access**
  - File-system security + Network & Compute isolation mechanisms

SUMMARY

1. **Create customizable compute environments with appropriate protections to ensure control is maintained**
2. **Leverage isolation mechanisms at compute, network, file-system layers to create secure & high-performance enclaves**

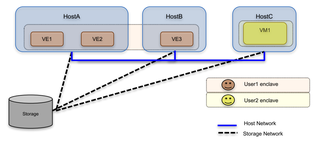


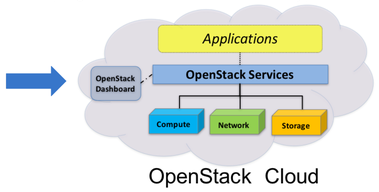
Objectives

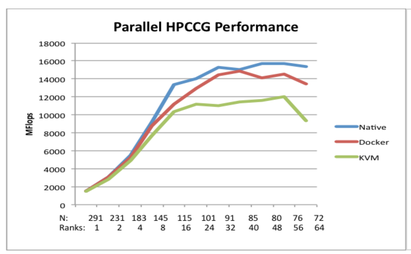
- **Secure Compute Node Customization**
  - Customizable environments and utilization of shared services
  - Low-latency, low-jitter, and high bandwidth
- **Network Enclaving**
  - Configure on demand and isolate network traffic
  - Low-latency, high-bandwidth communication
- **Secure Shared Storage**
  - Ability to isolate access to shared storage on per-enclave basis
  - High-bandwidth and high IOPS

Approach

- **OpenStack-based Prototype**
  - Component based platform for deployment, management & usage
  - Rich set of interfaces & components to map secure enclaves
    - Tenant abstraction, SDN Interfaces/plugins, Different virtualization types

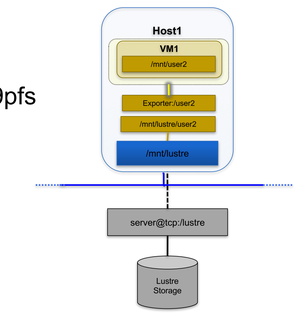






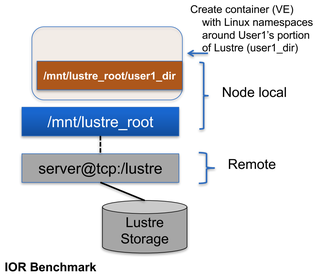
VM Access to Parallel Filesystem

- **Re-Exporting Host Filesystem**
  - RPC based "IO Forwarding"
  - Network File System (NFS) vs. VirtFS/9pfs
- **Setup**
  - Host mounts Lustre
  - Host exports VM's section of Lustre
  - VM (KVM) accesses Lustre via IOFwd



VE Access to Parallel Filesystem

- **Bind-mounted share of Filesystem**
  - Avoid need for IO-Forwarding
  - Single OS offers (near) native performance
- **Setup**
  - Host mounts Lustre
  - Host bind-mounts VE's section of Lustre
  - VE (LXC) access Lustre via mounted region



Status & Next Steps

- **Container-based virtualization shows great promise**
  - Efficient & secure high-performance compute enclaving
  - Near or slightly better IOR performance in VE vs. Native
- **Hypervisor-based very good performance with VirtFS**
  - IO-Forwarding of Lustre from host to VE ~15-20% < Native
- **Leverage OpenStack and SDN for on-demand enclaving**
  - Switch level enforcement with dynamic reconfigurable VLANs
  - User-creatable networks & user-customizable compute instances

Computational Research & Development Programs

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