Virtualization Technologies In Modern HPC Systems

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Virtual Open Systems

Exascale HPC Workshop, Ljubljana, Slovenia

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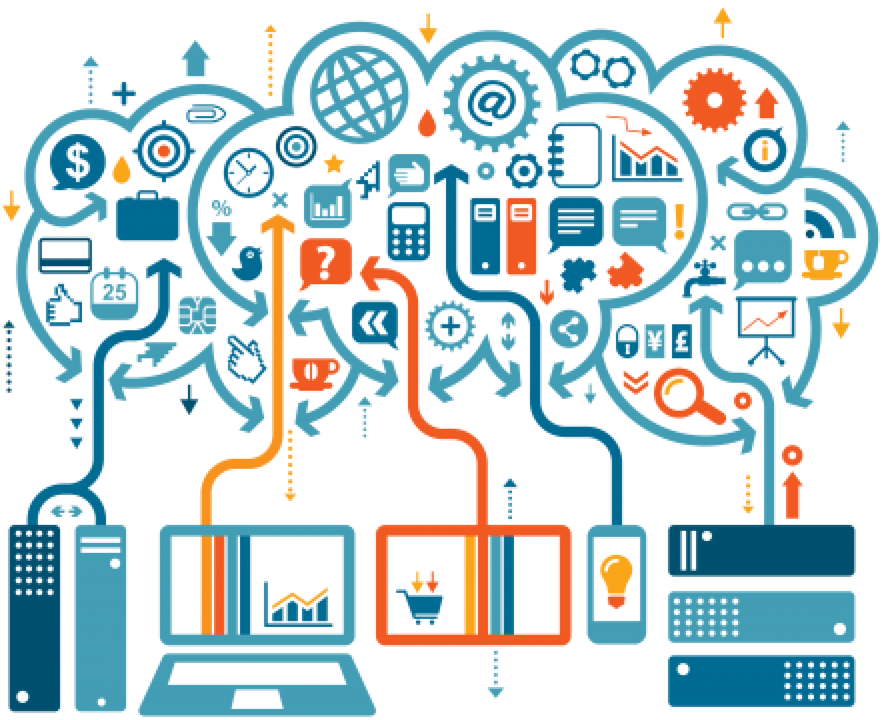
Horizon 2020

Virtualization Technologies In Modern HPC Systems

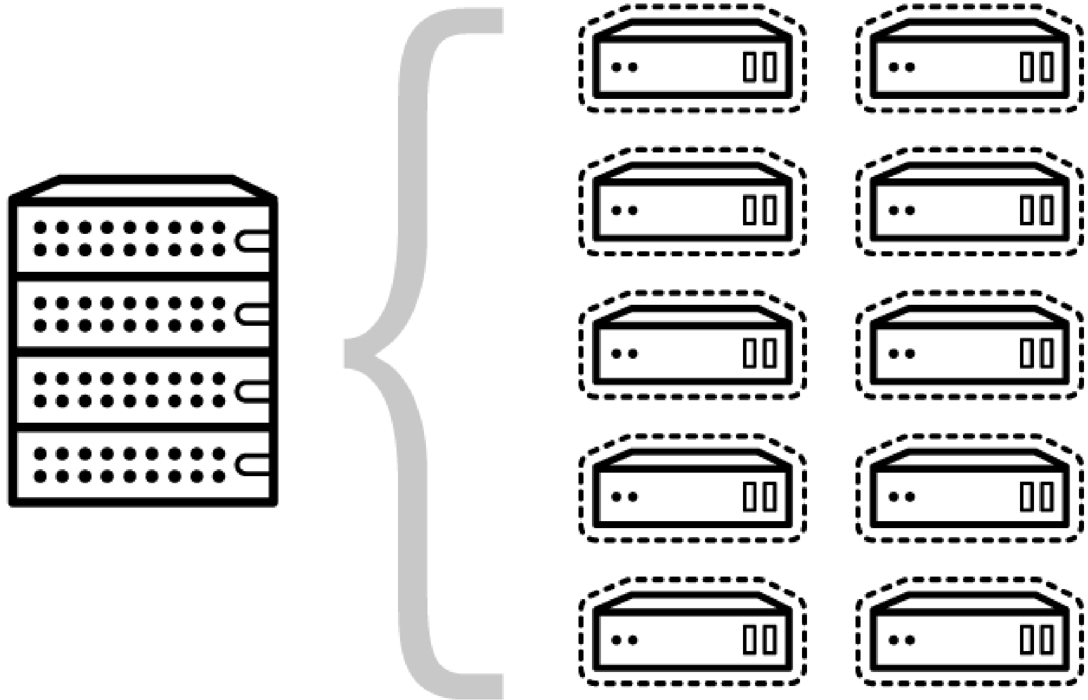
- Virtualization in HPC Systems
- Software Switches
- API Remoting
- Conclusions

Why virtualization on HPC?



- Increasing amount of data from various sources
- More industries adapting to fields like Big Data analytics
- Growing demand for HPC systems

The benefits of virtualization in HPC



- Virtualization can help to cope with the increasing demand
- Sharing compute resources means better hardware utilization of the HPC system
- Customize and orchestrate the HPC system specifically for the workload and deliver features like auto-scaling, etc.

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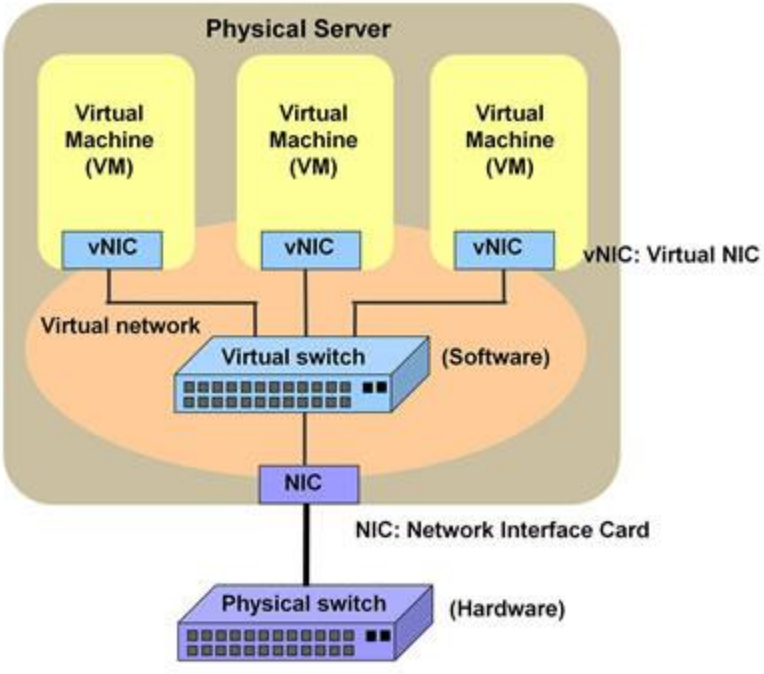
What is a software switch?



- Integral part of a virtualized system
- Provides the networking connectivity between the virtual machines
- Implements features for security, QoS and automated control

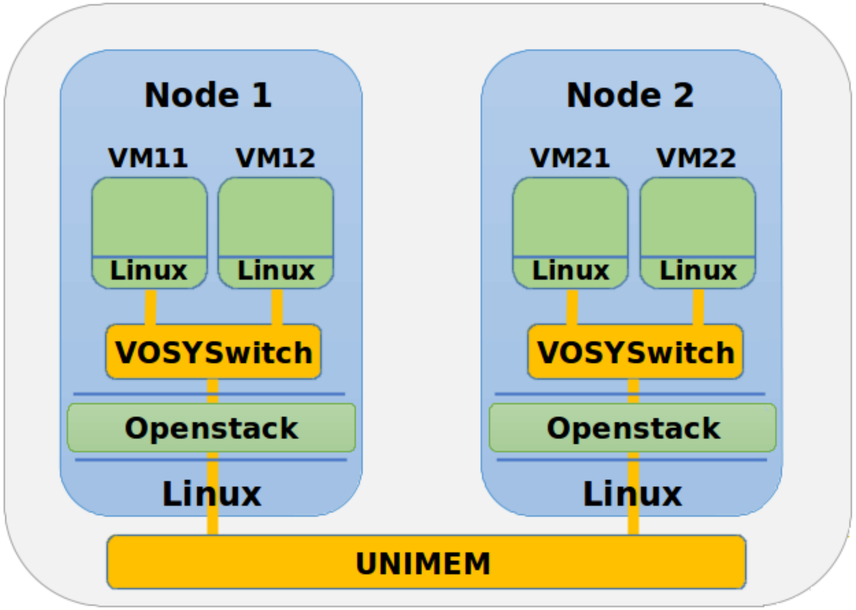
VOSYSwitch

- High-performance software switch based on a fast packet forwarding framework called Snabb
  - VOSYSwitch implements the NIC driver in user space
  - no context switches during packet handling
  - delivering near native performance
  - Supports both X86_64 and aarch64 platforms
- Fast and easily configurable through a simple JSON file

Adaptation of software switches to HPC - OpenStack

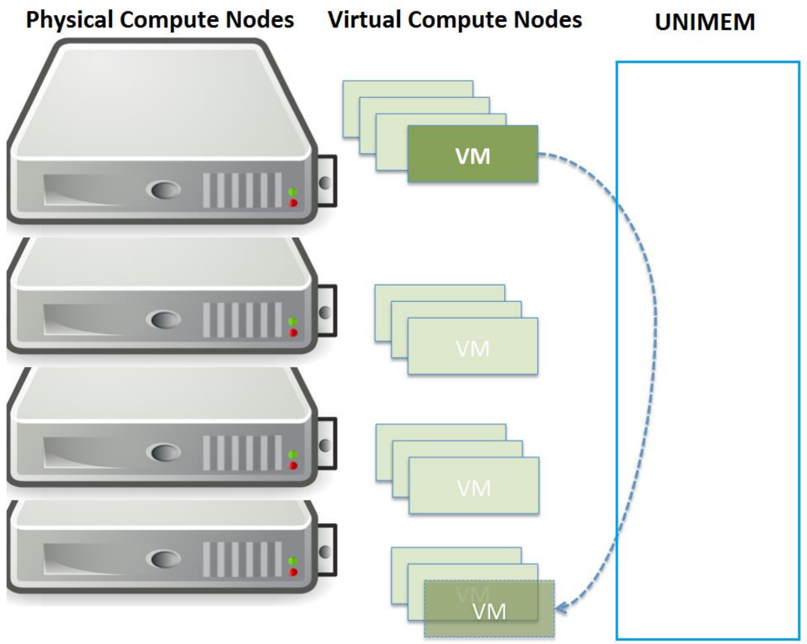
- How to manage a pool of servers and orchestrate a virtual system on top of that?
- OpenStack integration done in T2.4[ExaNeSt]
- Achieved through a dedicated ML2 plugin for Neutron
- Easy automated deployment of OpenStack w/VOSYSwitch for VM traffic
- Support for Devstack

Adaptation of software switches to HPC - UNIMEM



- UNIMEM is a scalable shared memory architecture
- VOSYSwitch support for UNIMEM
  - Achieved by developing an additional driver for UNIMEM in the core Snabb framework
- Relies on UNIMEM GSAS to exploit the high-performance shared memory of the ExaNeSt project for inter-node connectivity

Adaptation of software switches to HPC – Live Migration



- Migration is a one of the key benefits of a virtual system
- Implemented support for Live Migration over UNIMEM:
  - Support for VHU protocol features by a separate bitmask
  - Support for broadcasting fake RARP request messages
  - VOSYSwitch establishes a connection between the two nodes

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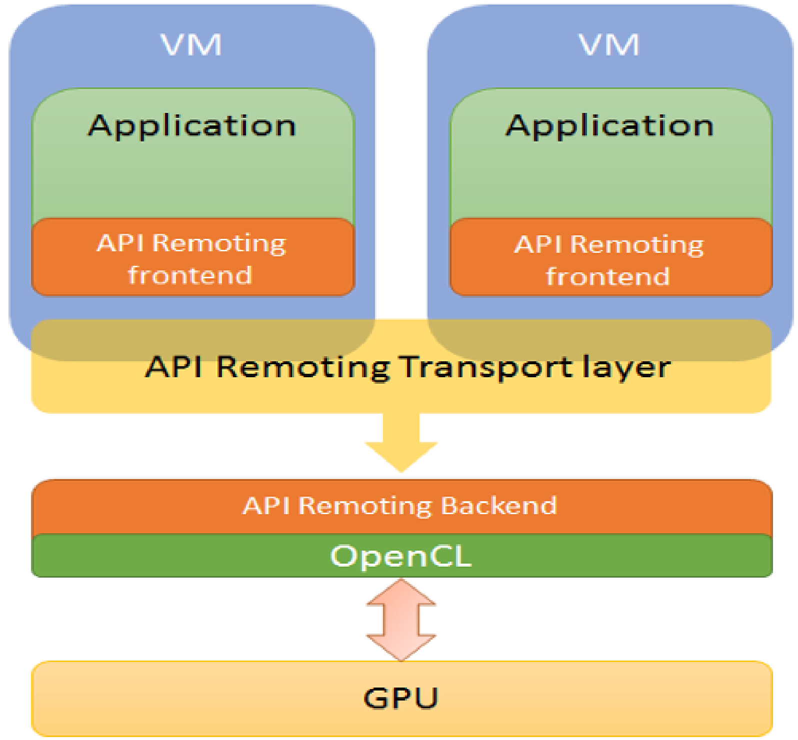
Introduction to API Remoting

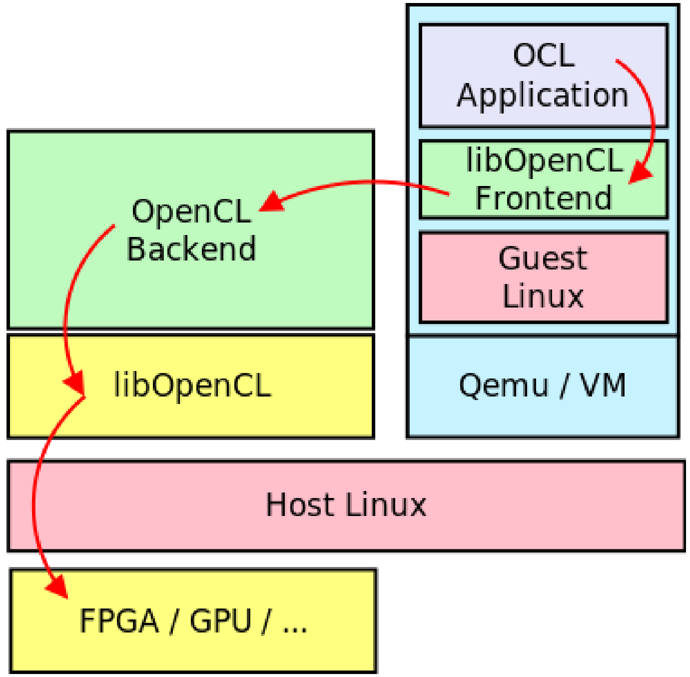


- In general, VMs cannot have access to the underlying hardware
- Virtualizing a device through its programming API interface (for ex. OpenCL, MPI, GSAS)
- Guest applications can leverage the HW through its API with no changes to their source code and no need for the hypervisor to provide a virtual HW abstraction

OpenCL in ExaNoDe and ECOSCALE

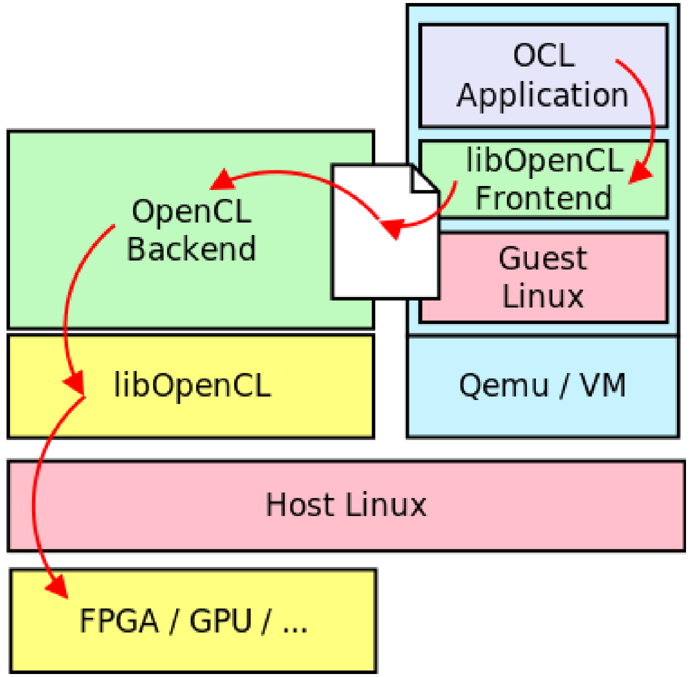
- Open standard for heterogeneous computing
  - Framework/API for controlling the computation
    - Work preparation and off-loading
    - Memory transfers
  - C-based programming language
    - Compiled on the fly
    - Executed on the accelerators
    - Task- and data-based parallelism
- Partners working at all layers of the OpenCL stack
  - ECOSCALE project brings it to the FPGA accelerator
  - ExaNeSt WP2 partners port scientific applications on top of it
  - ExaNoDe WP3 partners port the high-level data-flow programming models of OpenStream on top of it
  - ExaNoDe (VOSYS) enables using it inside virtual machines

API Remoting of OpenCL



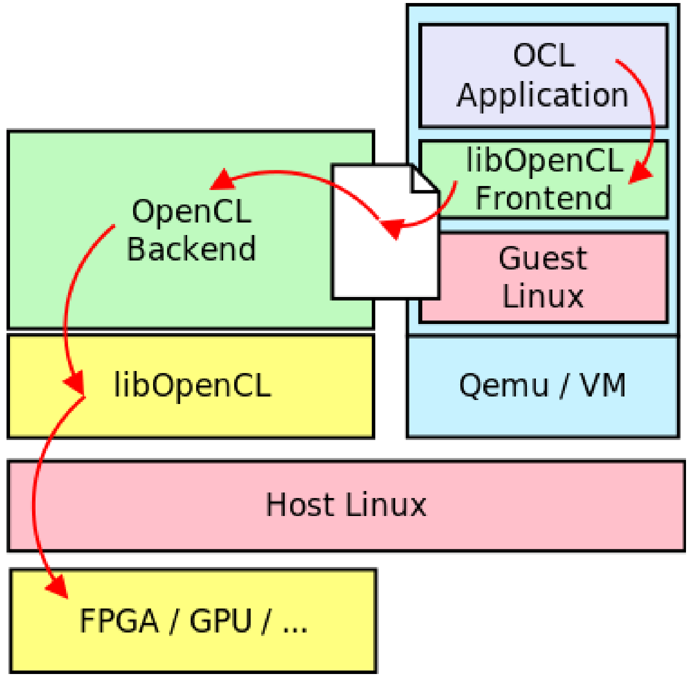
- Guest side:
  - OpenCL application is unchanged, but linked to our custom OpenCL library (called “**frontend**”) that forwards the calls to the backend
- Host side:
  - The **backend** is a host process that listens for calls from the frontends and does the actual call to the OpenCL library on the host

API Remoting of OpenCL



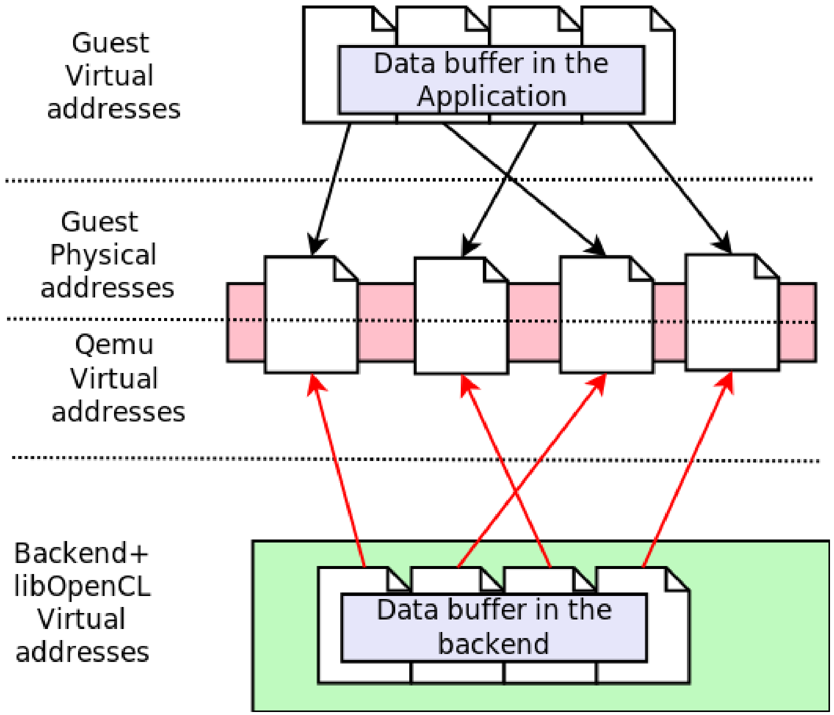
- The communication channel: **a shared page**
  - Host: Allocated in the host kernel module, mapped by the backend and then by QEMU and available in the guest address space
  - Guest: Mapped by the frontend library

API Remoting of OpenCL



- What about buffers bigger than a page?
- Naïve way:
  - Allocate more pages -> costly + many useless copies
- Better way:
  - Direct access to application buffer

API-Remoting of OpenCL – Zero-copy buffer passing



1. In the frontend:
   - Look up the guest physical addresses(GPA) making up the buffer
2. In the backend:
   - Load QEMU RAM buffer
   - Translate the GPA into valid virtual addresses
   - Remap contiguously the pages
   - Pass the buffer to OpenCL

What about buffers bigger than a page?

- Naïve way:
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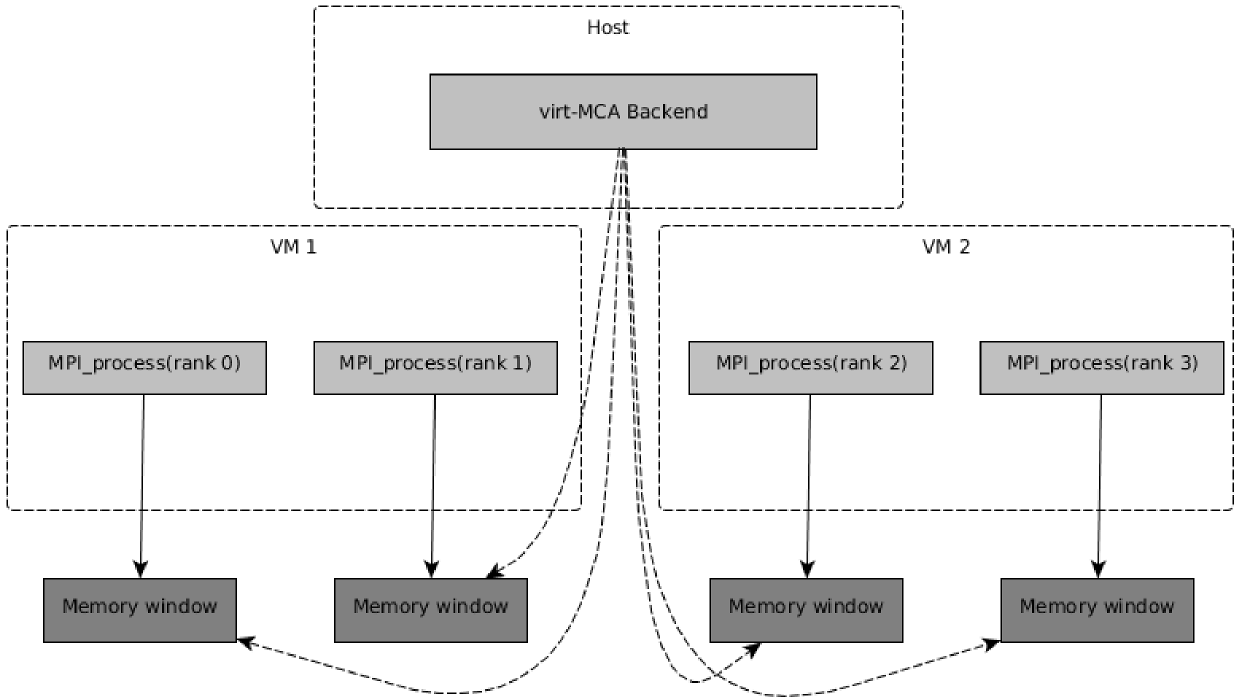
API-Remoting of Intra-node MPI One-Sided Communication

- Target:
  - to enhance the performance of OSC traffic for VMs that reside in the same node
  - acceleration of the Remote Memory Access communication mechanisms
- Implementation based on OpenMPI 3.1
- An extension of the ‘pt2pt’ component for OSC
- The ‘virt’ extension uses a mix of TCP/IP and shared memory for processes communication transfers

API-Remoting of Intra-node MPI One-Sided Communication
The ‘virt’ extension of ‘pt2pt’



- Memory window allocations shared with the ‘backend’ process
- The backend has direct access on node’s memory buffers
- One-Sided transfers e.g., MPI_Put, MPI_Get use the backend to copy the data via shared memory
- Traffic out of the node fall back to the ‘pt2pt’ component

API-Remoting of MPI One-Sided Communication Preliminary Results

- Evaluated the system using Ohio's OSU-Micro-Benchmarks for One-Sided Communication
- Test cases:
  - Bandwidth and Latency tests with variable sized memory window buffers
- Up to 4x in bandwidth speedup
  - The bandwidth increases linear with the window size
  - Latency is not affected due to the preliminary TCP/IP communication for synchronization

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Conclusions

- Projects like ECOSCALE, ExaNeSt and ExaNoDe aim to set the ground for modern cutting-edge HPC systems through novel hardware and software solutions.
- Innovations brought by these projects introduce unexplored possibilities for the current technologies like software switches and virtualization techniques like API remoting.

Thank you!

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