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Agenda

• Why Infiniband Virtualization?
• I/O Virtualization models
  • Software based sharing
  • Hardware based I/O virtualization with SR-IOV
• Case study with OVM/Xen and Oracle Sun Fire systems
  • Implementation
  • Network configuration
  • VM configuration
  • Issues pending and early performance results
• Conclusions and QA
Motivation behind Virtualization

- A physical server can be virtualized in multiple logical servers.
- Each logical server or VM (Virtual Machine) run on top of VMM (Virtual Machine Monitor) or Hypervisor.
- Each VM can run its own OS and share or own its own physical resources (CPU, Memory, I/O,..).
- VMM controls the resources VM’s resources and provides services like VM manage Live Migration of VM, dynamic resources allocation and load balancing.
- This is useful for cloud environment, consolidation and over all improve the physical server utilization and total cost of ownership.
Infiniband Virtualization Model

Software based I/O virtualization

• Very easy to set in motion, transparent to existing VM environments, only solution to rip all all benefits from Virtualization (e.g. Load Balancing, LiveMigration, PV VM, …)

• Performance impact on I/O latency and bandwidth

Hardware-based I/O virtualization (bypass)

• I/O performance is significantly improved

• CPU usage is reduced (better server utilization)

• Virtualization features not always available (LiveMigration, PV VM, PoD..)
Software based I/O virtualization in Xen

- Virtual Bridging allow VM to be fabric agnostic
- VM relies on an emulated, generic Ethernet NIC for I/O
- Emulated NIC communicates with Infiniband HCA through a virtual Bridge in Dom0
- Infiniband driver stack installed only in Dom0
- Application in DomU can not leverage native Infiniband features or RDMA-enabled protocols.
SR-IOV Virtualization with Xen

- SR-IOV exposes VF enabling Infiniband access for VM
- PF is hosted in Dom0 and is responsible for dynamic allocation of IB resources (PKeys, QP, CQ, memory region,…) to the VFs
- PF owns QP0 and virtualize QP1 to make it available to all VMs
- Each VM has the Infiniband stack instantiated and can leverage RDMA-enabled protocol for enhanced performance.
SR-IOV Infiniband constraints

- A VF configuration space provides access to registers to perform I/O only (e.g. Access only DMA channels and related registers).
- The H/W related configuration changes can only be performed via the PF. VF driver needs to interact with PF driver to perform VF’s operations. PF driver is responsible to ensure a VF does not impact other VFs or PF in any way.
- This restrict the management IB commands available from the VMs (SM commands only available from Dom0).
- The view of the Infiniband network is different from the privileged VM (Dom0) and the other VMs (DomUs).
- Some Virtualization features are not supported (save/restore, Live Migration)
Case study environment

- Create Database clusters between 2 (8 sockets) servers
- Each server host 8 VMs
- Each cluster contains 2 VMs
- 3 types of VM:
  - Large: 20 cores, 4VFs, 512GB
  - Medium: 10 cores, 2VFs, 256GB
  - Small: 5 cores, 1VF, 128GB
- Clients connections use SDP and IPoIB
- Storage access relies on RDS
Case study goals

- Use Active-Active and Active-Passive IB bonding in each VM
- Network QoS to provide automatic and transparent prioritization of latency sensitive messages
- Infiniband Partitioning for isolation between the virtual DB clusters
- Validate client connections to DB (SDP, IPoIB) and storage (RDS)
- Validate the full stack for both stability and performance.
Test Bed / Stack

- Server Hardware Exadata X2-8
- 8 x Ten-Core Intel® Xeon® E7-8870 Processors (2.40 GHz)
  - 2 TB Memory
- Chipset support for VT-d and VT-x
- Bios support for SR-IOV, MMIO 64bits
- HCA HW (ConnectX2 MT26428)
  - 8 x InfiniBand QDR (40Gb/s) Ports (4 HCAs)
- Linux distribution in the Guest
  - Oracle Linux 6 (Kernel UEK2 2.6.39)
- OFED (1.5.5-2)
- Oracle VM Server 3.2 (Xen 4.3.1, Linux kernel UEK2 2.6.39)
- Protocol utilized: IPoIB, RDS, SDP

To enable virtualization all pieces of the puzzle need to support virtualization and Infiniband
Server VM IB Setup

- Dom0 manages all PFs
- DomU can have multiple VFs assigned:
  - VFs come from different HCAs
  - VF IB ports are bound together for HA
Network configuration

- IB Bonding support
  - Linux bonding (active-passive) with CX2 HCAs
  - Active Bonding (active-active) with CX3 HCAs
  - Performance benefit from PCIe gen3 systems
  - Enabled via RDS module parameter
  - VF VGUID generated by the PF driver
  - based on the Dom0 PF unique GUID
  - For RDMA with FMR – Dom0 runs both mlx4_xen_fmr_master & slave drivers while DomUs only run the slave driver
  - Overall network configuration matches bare metal and follows the same naming convention (bondib0, ib0, ib0.pkey)
PCI Pass-Through configuration

- Determine the BDF (Bus Device Function) of the VF you want to pass through:
  
  ```sh
  #lspci
  ....
  08:00.0 InfiniBand: Mellanox Technologies MT26428 [ConnectX VPI PCIe 2.0 5GT/s - IB QDR / 10GigE] (rev b0)
  08:00.1 InfiniBand: Mellanox Technologies MT25400 Family [ConnectX-2 Virtual Function] (rev b0)
  ...
  ```

- Assign the device to pciback instead of its normal driver in Dom0
  
  ```sh
  #modprobe xen-pciback
  #echo 0000:08:00.1 > /sys/bus/pci/devices/0000:08:00.1/driver/unbind
  #echo 0000:08:00.1 > /sys/bus/pci/drivers/pciback/new_slot
  #echo 0000:08:00.1 > /sys/bus/pci/drivers/pciback/bind
  ```

- Verify that the VF is ready to be attached to the VM
  
  ```sh
  #xm pci-list-assignable-devices
  ....
  0000:08:00.1
  ....
  ```

- Add the list of VF you want to assigned to the VM in `vm.cfg`
  
  ```
  pci=['08:00.1']
  ```
PKeys configuration with SR-IOV

• Standard PKeys configuration remains the same in Dom0 and DomU:
  
  ```
  # ls /etc/sysconfig/network-scripts/
  ifcfg-ib0
  ifcfg-ib0.c458
  ifcfg-ib0.8002
  ...
  ```

• List available PKeys configured for given PF in Dom0
  
  ```
  ## cat /sys/class/infiniband/mlx4_0/iov/ports/1/pkeys/[0-127]
  0x7fff
  0x8002
  0xc458
  ...
  ```

• Assign PKeys to each VF in Dom0
  
  ```
  # echo none > /sys/class/infiniband/mlx4_0/iov/0000:08:00.1/ports/1/pkey_idx/[0-127]
  # echo 0 > /sys/class/infiniband/mlx4_0/iov/0000:08:00.1/ports/1/pkey_idx/0
  # echo 2 > /sys/class/infiniband/mlx4_0/iov/0000:08:00.1/ports/1/pkey_idx/2
  ```
Xen Guest VM configuration

- HVM VM configuration only (no PV VM)
- VM CPU and Memory allocation
  - Memory allocation should be fixed at VM creation time
  - Memory ballooning is disabled because of PCI Pass-through
  - vCPUs pinning to physical CPUs should be done also at creation time
    - Floating vCPU cause performance issues
    - Ensure memory allocation come from local memory domain
- VFs assigned to each VM need to be explicit set in the VM configuration file
- VF hot-plug is not supported
Pending issues and limitations

- Dynamic memory add/remove not supported
- PCI Pass-Through will prevent Xen operation like save/restore and Live Migration
- Non Transparent Live Migration using ULP that support connection failure/re-establishment like RDS planned in the future with the current HCA generation
- VM needs to be started with pause/un-pause options
- IB management commands restricted in DomU
- Different views of the IB network from Dom0 and DomU
- Stability
  - Fixes required across the stack (FW, BIOS, Kernel, Xen/ OVM).
  - More issues found on large systems (e.g. 8 sockets)
Performance consideration

- Overall VF-to-VF bandwidth close to PF-to-PF (5% to 15% impact)
- Less interrupt vectors per VF (3) in each VM in comparison to bare metal (24) – this has an impact as we scale up connections.
- We maintain 2 pools of FMRs (8k and 1M) which are resized and rebalanced dynamically to avoid running periodically out of FMRs
- NUMA impact is important
  - Pin VM vCPUs to physical CPUs
  - NUMA topology not available in VMs
  - Hyper threading visibility not available to VM kernel.
- Scalability
  - Number of VMs capped by the number of VFs
  - Over provisioning causes performance impact
- Best option is to dedicate vCPUs to each VMs
Conclusion and QA

• IB SR-IOV virtualization support improves performance in comparison to software based approach

• The full stack needs to support SR-IOV

• Xen SR-IOV support present but requires significant planing.

• Validated support for ULPs we need (IPoIB, RDS, SDP), bonding, QoS and PKeys in Guest VM.

• During our evaluation journey many bugs were found across the stack and fixed (~20 bugs).

• Future work will focus on performance and scalability