OPENFABRICS ALLIANCE

12th ANNUAL WORKSHOP 2016

RDMA CONTAINERS UPDATE

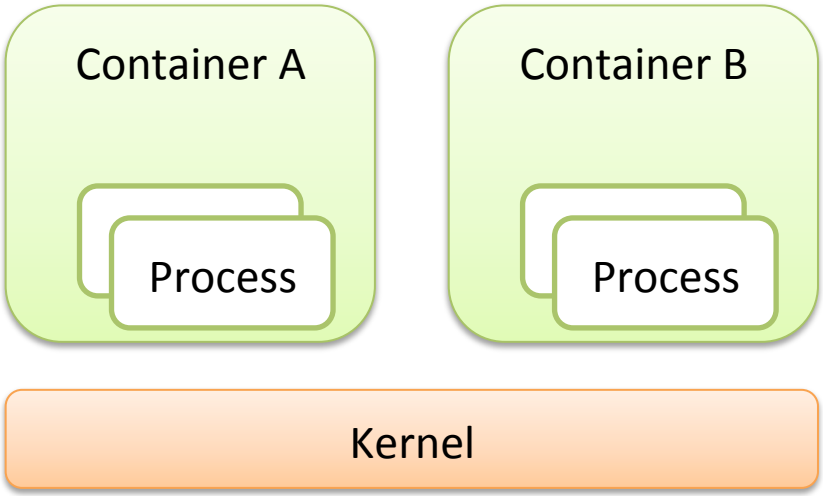
Haggai Eran, Liran Liss, Mellanox Technologies

Parav Pandit, Hewlett Packard Enterprise

April 5th, 2016

CONTAINERS

- **Isolation**
- **Resource control**
- **Lightweight virtualization**



BENEFIT OF CONTAINERS

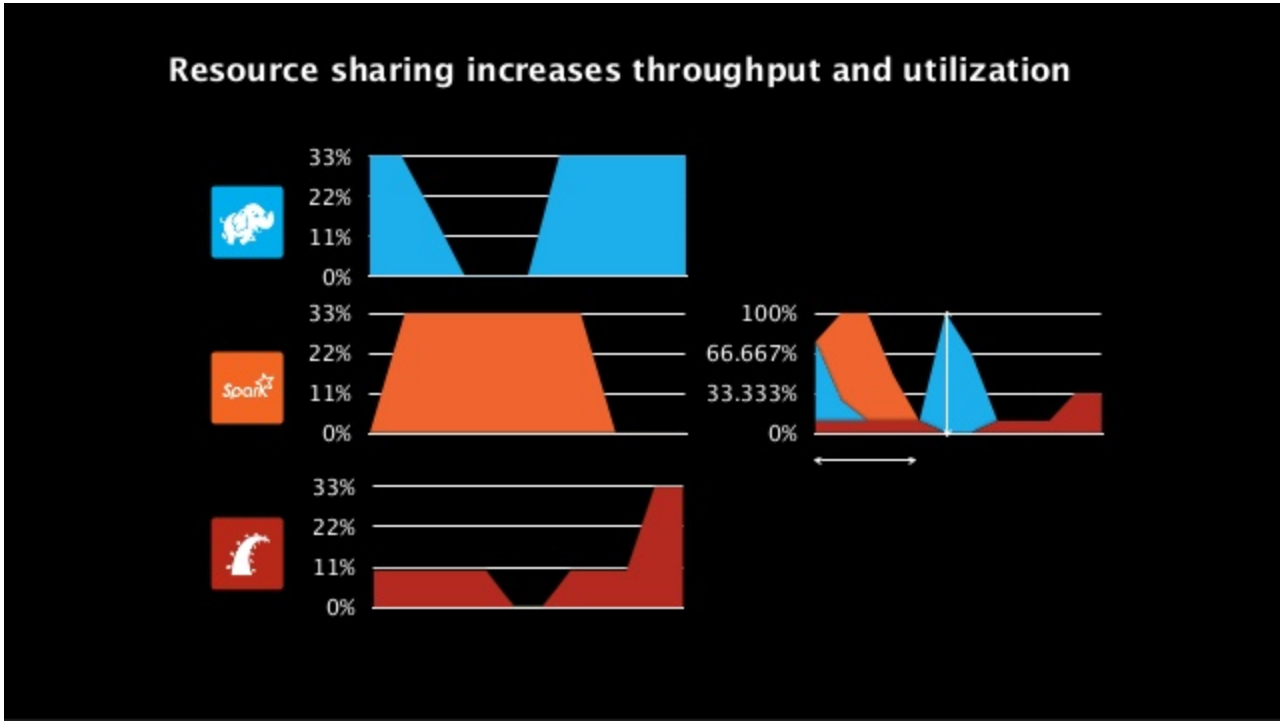
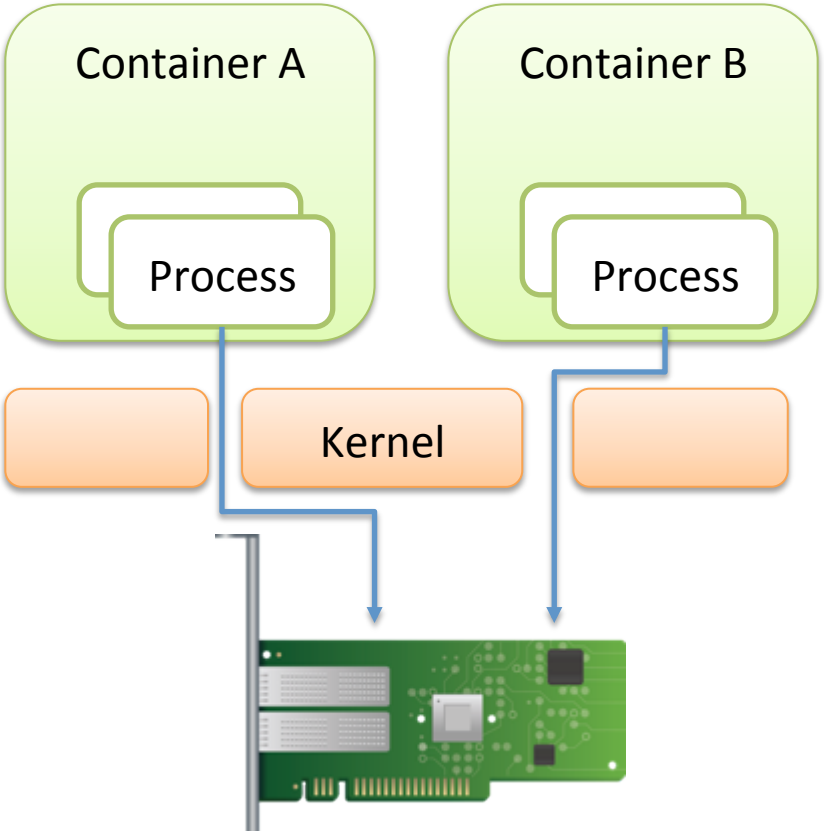


Image credit: [Apache Mesos at twitter Texas Linuxfest 2014]

RDMA CONTAINERS

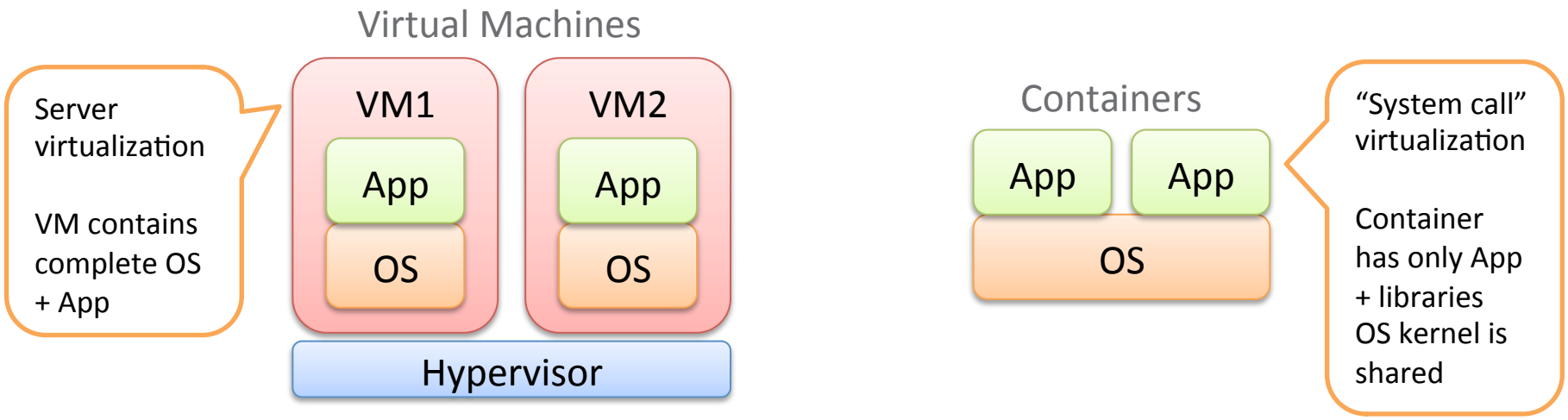


AGENDA

- **Containers 101**
- **RDMA network namespace support**
  - InfiniBand
  - RoCE
- **RDMA cgroup**
- **Future work**

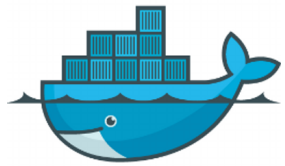
CONTAINERS 101

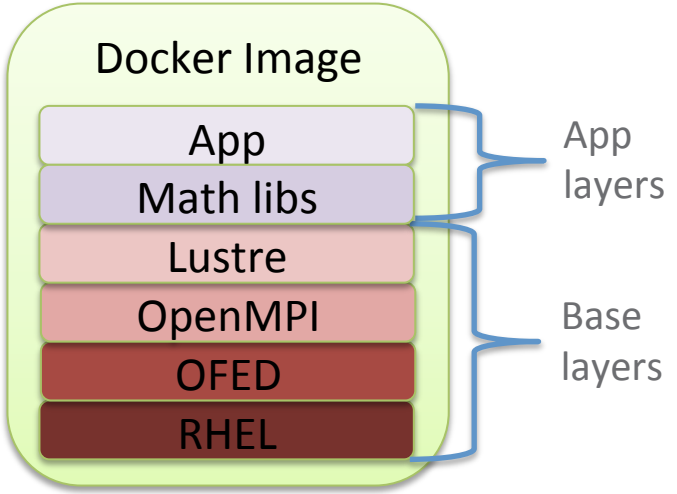
- **A server-virtualization technology for running multiple isolated user-space instances**
- **Each instance**
  - Has the look and feel of running over a dedicated server
  - Cannot impact the activity of other instances
- **Containers and Virtual Machines (VMs) provide virtualization at different levels**



EXAMPLE: DOCKER

- **Open platform to build, ship, and run distributed apps**
  - Based on Linux container technology
- **Main promise**
  - Easily package an application and its dependencies
    - Regardless of the language, tool chain, and distribution
    - Layered images
    - Large application repository
      - Basis for further specialization
  - Deploy on any Server
    - Regardless of OS distribution
    - Regardless of underlying architecture
  - Lightweight runtime
    - Rapid scale-up/down of services





LINUX CONTAINERS = NAMESPACES + CGROUPS

- **Namespaces**
  - Provide the illusion of running in isolation
  - Implemented for multiple OS sub-systems
- **cgroups**
  - Restrict resource utilization
  - Controllers for multiple resource types

Namespace examples

Name space	Description
pid	Process IDs
net	Network interfaces, routing tables, and netfilter
ipc	Semaphores, shared memory, and message queues
mnt	Root and file-system mounts
uts	Host name
uid	User IDs

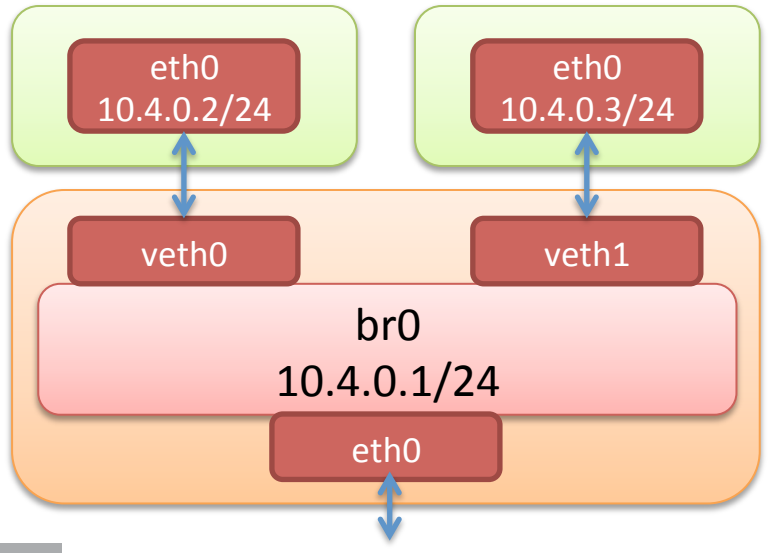
cgroup examples

Controller	Description
blkio	Access to block devices
cpu	CPU time
cpuset	CPU cores
devices	Device access
memory	Memory usage
net_cls	Packet classification
net_prio	Packet priority
RDMA	*RDMA resources. Explained later.*

CONTAINER IP NETWORKING

- **Common models**
  - Host
  - Physical interface / VLAN / macvlan / ipvlan
    - Container has global IP
  - Bridge
    - Container has global IP
  - Pod (e.g., GCE)
    - Multi-container scheduling unit
    - Global IP per POD
  - NAT (e.g., Docker)
  - Tunneling (VXLAN with docker multi-host)

- **Building blocks**
  - Network namespaces
    - Interfaces, IP tables, netfilter
  - Virtual networking
    - bridge, ovs, NAT
    - macvlan, vlan, veth



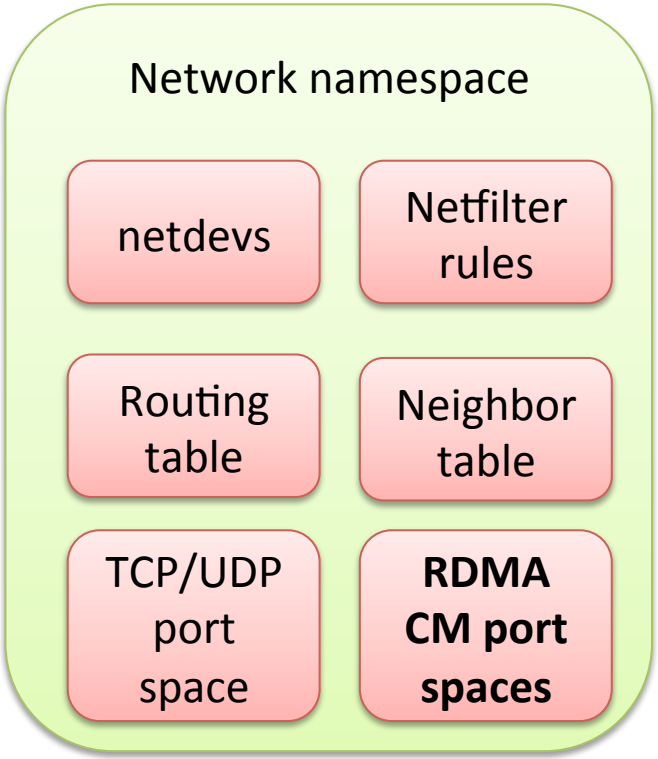
RDMA NETWORK NAMESPACE SUPPORT

RDMA ISOLATION DESIGN GOALS

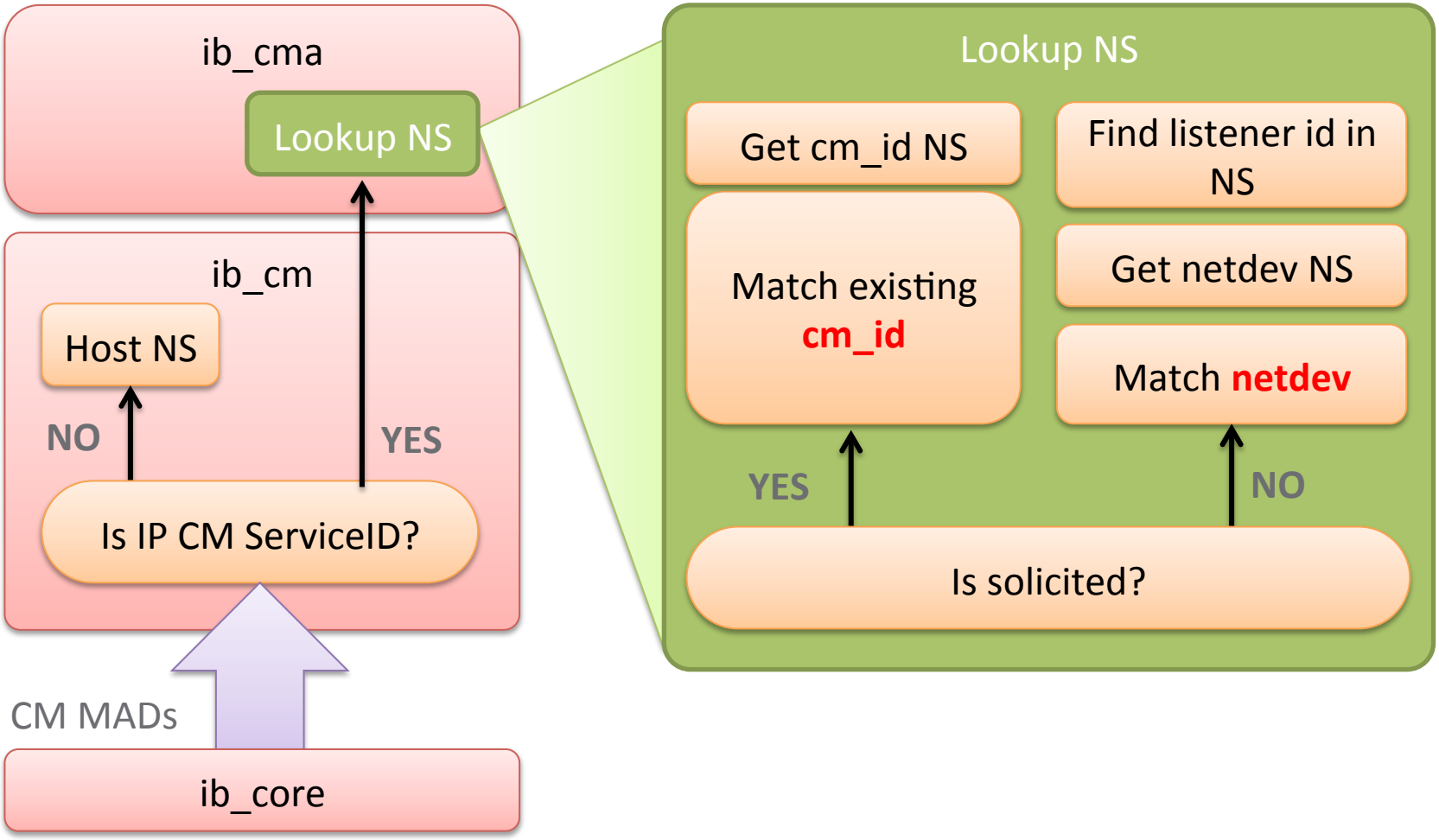
- **Simplicity and efficiency**
  - Containers share the same RDMA device instance
  - Leverage existing isolation infrastructure
    - Network namespaces and cgroups
- **Focus on application APIs**
  - Verbs / RDMACM
  - Exclude management and low-level APIs (e.g., umad, ucm)
    - Deny access using device controller
  - Exclude kernel ULPs (e.g., iSER, SRP)
    - Not directly exposed to applications
    - Controlled by other means (blk_io)
    - Subject for future work

RDMA CM IN NET. NAMESPACE

- **Have per-namespace RDMA CM port spaces**
- **Upon creation of an rdma_cm_id associate it with the creating process's namespace**
- **De-multiplex requests**



MAD SERVICEID RESOLUTION

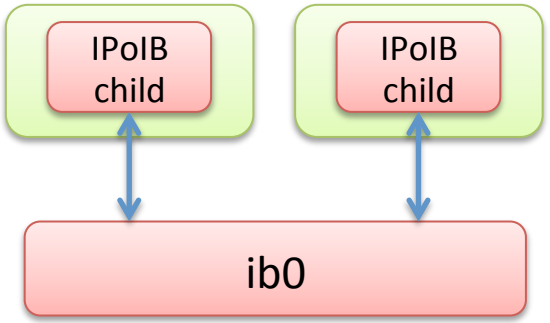


INFINIBAND NETWORK NAMESPACE

- **Initial proposal**
  - No need for support at the verbs level
    - No user-chosen well-known QPs, R_Keys.
  - RDMA CM support for network namespace
    - Select net namespace for incoming RDMA CM requests based on:
      - IB device
      - Physical port
      - IP address
      - P_Key
- **Rejected because demux doesn't look at the GID**

INFINIBAND UPSTREAM SUPPORT

- **Modified proposal was accepted into kernel 4.4**
- **De-mux incoming requests according to:**
  - IB device
  - Physical port
  - **GID** (treat as a layer two address)
  - P_Key
  - Analogous to macvlan



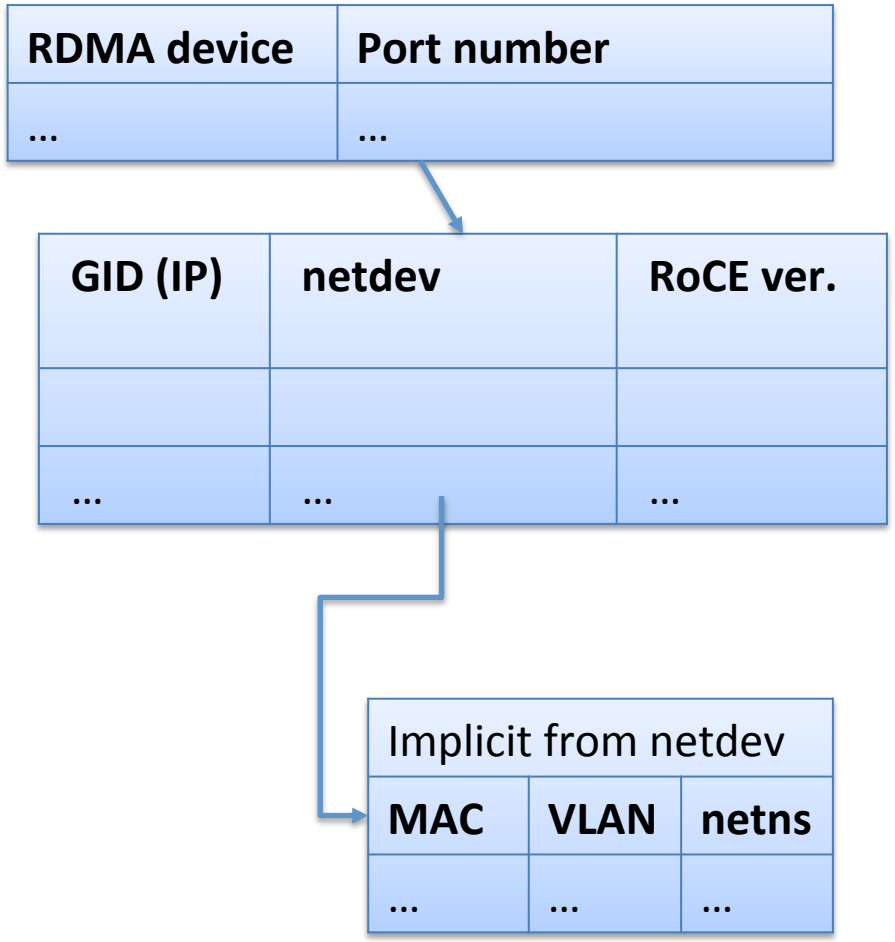
- **If above properties don't provide a unique namespace**
  - (e.g. when creating multiple interfaces with `ip link add`)
  - Use IP address to de-mux
  - Analogous to ipvlan

ROCE NET. NAMESPACE SUPPORT

- **De-mux RDMA CM requests**
  - Use new GID table
- **verbs: Route and neighbor lookup**
- **Filter supported GIDs**

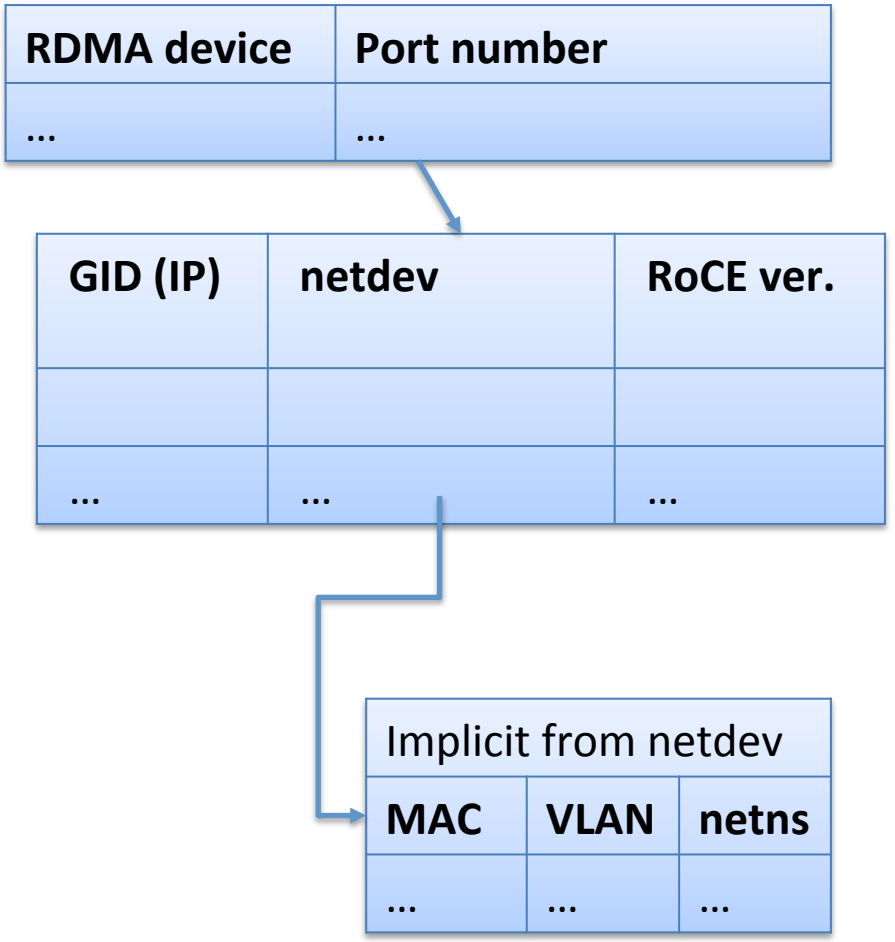
ROCE GID TABLE

- **Kernel v4.4 added code using new RoCE GID table to the core**
- **Each GID is associated with its netdevice**
- **The netdevice is associated with its net namespace**
- **Code automatically adds new GIDs for**
  - New IP addresses
  - macvlan / vlan devices
  - bonding devices



ROCE NET NAMESPACE DE-MUX

- **De-muxing RDMA CM requests becomes as simple as finding the matching GID for an incoming request**
  - RDMA device
  - Physical port
  - MAC
  - VLAN
  - IP address
  - RoCE version



VERBS ROUTE AND NEIGH. LOOKUP

- **RoCE does route and neighbor lookup**
  - Finding source GID, destination MAC and VLAN given a destination IP.
  - `ibv_modify_qp()` (RC change to RTR)
  - `ibv_create_ah()` (UD)
- **Do the route and neighbor lookup in the namespace of the calling process**

FILTER SUPPORTED GIDS

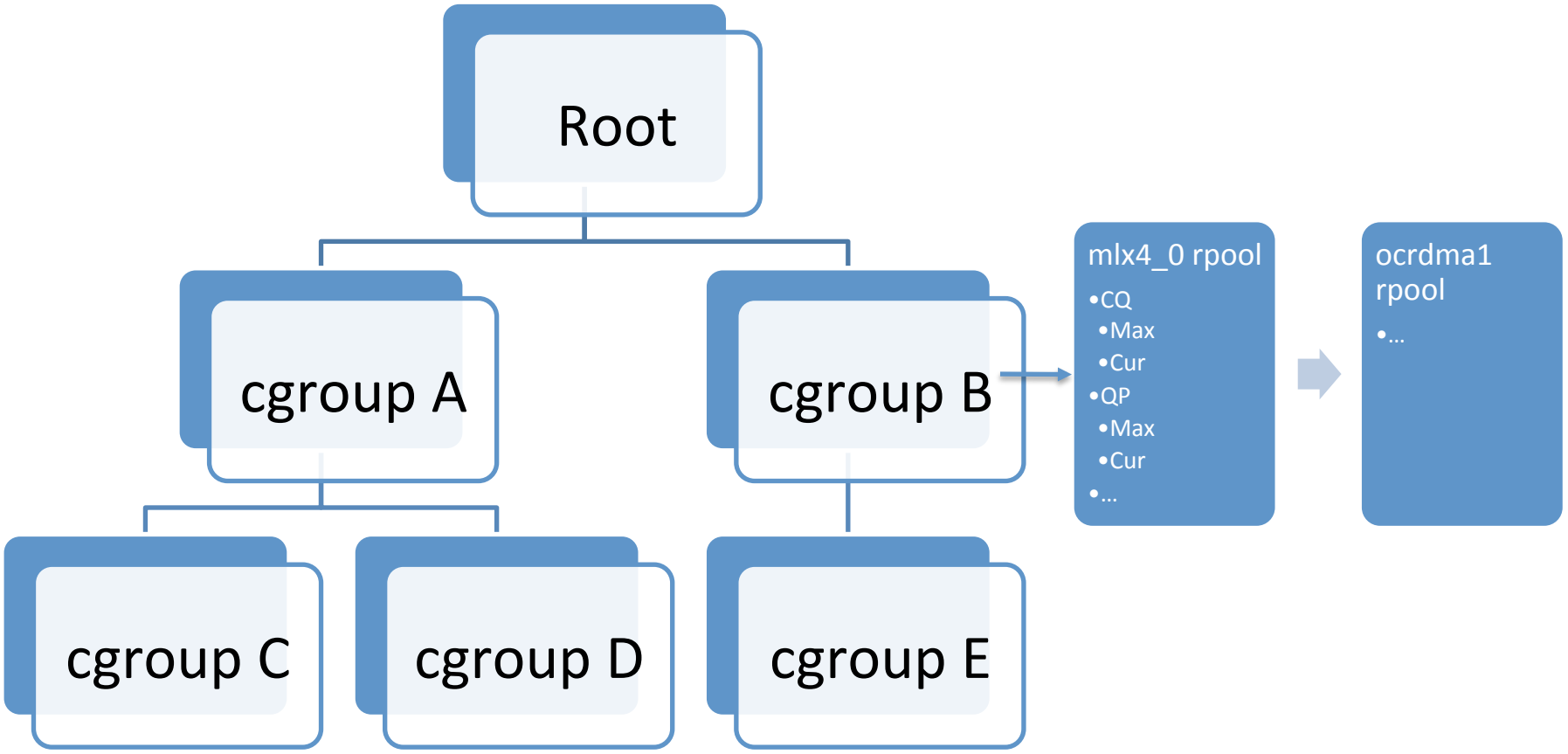
- **A RoCE devices' GID table includes GIDs from all namespaces**
- **Each process has to see only its own namespace's subset**
  - Filter sysfs GIDs
  - ibv_query_gid() is implemented by querying sysfs
- **Enforce only valid GIDs are passed to ibv_modify_qp and ibv_create_ah**

RDMA CGROUP

RDMA CGROUP CONTROLLER

- **Started as device cgroup extension, but community asked for dedicated cgroup.**
- **It is an individual rdma cgroup now**
- **Governs application resource utilization**
  - Per device resource configuration
  - For a process or a group of processes
  - Supports hierarchical resource accounting, allows running nested containers
  - Ensures applications cannot take away all the resources, allowing kernel consumers to make use of it.
- **Controlled resources**
  - Opened HCA contexts
  - AHs, CQs, PDs, QPs, SRQs, MRs, MWs, Flows
- **New RDMA cgroup resources can be defined and charged without kernel upgrade by the IB stack**

RDMA CGROUP IMPLEMENTATION



MIGRATING PROCESSES

- **Process charges resource to its cgroup**
- **Migrate to another cgroup**
  - Might even fork before migrating (shared resources)
  - Not a common use case so pick the simpler solution
  - Resource charging always occurs to current owner cgroup
  - After migration resources are changed to newer cgroup
  - Resources created before migration continues with older cgroup
- **Release resource**
  - Resources are uncharged from their original cgroup
  - Each resource (`ib_uobject`) points to its cgroup

RDMA CGROUP EXAMPLES

- **Raw file system level examples**
  - **Creating/Deleting rdma cgroup**

    #cgcreate –g rdma:c1

    #cgdelete –g rdma:c2
  - **Configuring resource limits**

    #echo mlx4_0 qp=10 mr=8 > /sys/fs/cgroup/rdma/c1/rdma.max
  - **Query resource limits**

    #cat /sys/fs/cgroup/rdma/c1/rdma.max

    Output:

    mlx4_0 uctx=max ah=max mr=7 cq=max srq=max qp=9 flow=max

    ocrdma0 uctx=max ah=max mr=max cq=max srq=max qp=max flow=max
  - **Delete resource limits**

    #echo mlx4_0 qp=max mr=max > /sys/fs/cgroup/rdma/c1/rdma.max
  - **Query resource usage**

    #cat /sys/fs/cgroup/rdma/c1/rdma.current

    Output:

    mlx4_0 uctx=max ah=max mr=8 cq=max srq=max qp=10 flow=max

    ocrdma0 uctx=max ah=max mr=max cq=max srq=max qp=max flow=max

RDMA CGROUP DOCKER INTEGRATION

```
From a1f87459e12055b287adefcb79cc8ef9b9b3dc6c Mon Sep 17 00:00:00 2001
From: Parav Pandit <parav.k.pandit@hpe.com>
Date: Sun, 20 Mar 2016 18:15:31 +0530
Subject: [PATCH] cgroup/rdma: Added support for Rdma cgroup.

This patchset added support to configure rdma controller limits
of each container instance.
RDMA controller limits are configured at instance launch time using
--rdma-limit option.

It allows updating limits using Docker Remote API JSON extension
using "RdmaLimit" key.

Parav Pandit (1):
  cgroup/rdma: Added support for RDMA cgroup controller.

 daemon/container_operations_unix.go                |  1 +
 daemon/daemon_unix.go                              |  5 +++
 daemon/execdriver/driver_unix.go                   |  2 +
 pkg/sysinfo/sysinfo.go                             |  6 +++
 pkg/sysinfo/sysinfo_linux.go                       | 16 +++++++
 runconfig/opts/parse.go                            |  2 +
 .../engine-api/types/container/host_config.go      |  1 +
 .../runc/libcontainer/cgroups/fs/apply_raw.go      |  1 +
 .../runc/libcontainer/cgroups/fs/rdma.go           | 51 ++++++++++++++++++++++
 .../runc/libcontainer/cgroups/stats.go             |  5 +++
 .../runc/libcontainer/configs/cgroup_unix.go       |  3 ++
 11 files changed, 93 insertions(+)
 create mode 100644 vendor/src/github.com/opencontainers/runc/libcontainer/cgroups/fs/rdma.go
```

RDMA CGROUP DOCKER EXAMPLES

- **Resource configuration at starting Docker container:**
  - docker run –net=host --rdma_limit="mlx4_0 cq=10 qp=100 mr=4" -i -t /bin/bash

- **Docker Remote API**

Example request:

```
POST /containers/(id)/update HTTP/1.1
  Content-Type: application/json
  {
    "RdmaLimit": "mlx4_1 flow=100 qp=200",
  }
```

Example response:

```
HTTP/1.1 200 OK
  Content-Type: application/json
  {
     "Warnings": []
  }
```

- **Inside Docker instance**

#cat /sys/fs/cgroup/rdma/rdma.max

Output:

mlx4_1 uctx=max ah=max mr=7 cq=max srq=max qp=200 flow=100

STATUS

- **InfiniBand RDMA CM support in v4.4**
- **Working on RoCE net namespace support**
- **RDMA cgroup patches submitted**
- **RDMA cgroup Docker patches are ready, will be submitted once kernel patches are accepted**
- **Future work**
  - InfiniBand: limit P_Key usage in verbs applications
    - Perhaps extend the RDMA cgroup or use the new SELinux patches
  - QoS: limit container's bandwidth usage, SL, or VLAN priority
  - Raw Ethernet support

CONCLUSION

- **RDMA container technology provides HPC applications access to high-performance networking in a secure and isolated manner**

- **RDMA cgroups allow fine grained control over RDMA resource allowing better utilization of available hardware**

Thank you

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THANK YOU

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MOTIVATIONAL EXAMPLE