2020 OFA Virtual Workshop

RDMA WITH GPU MEMORY VIA DMA-BUF

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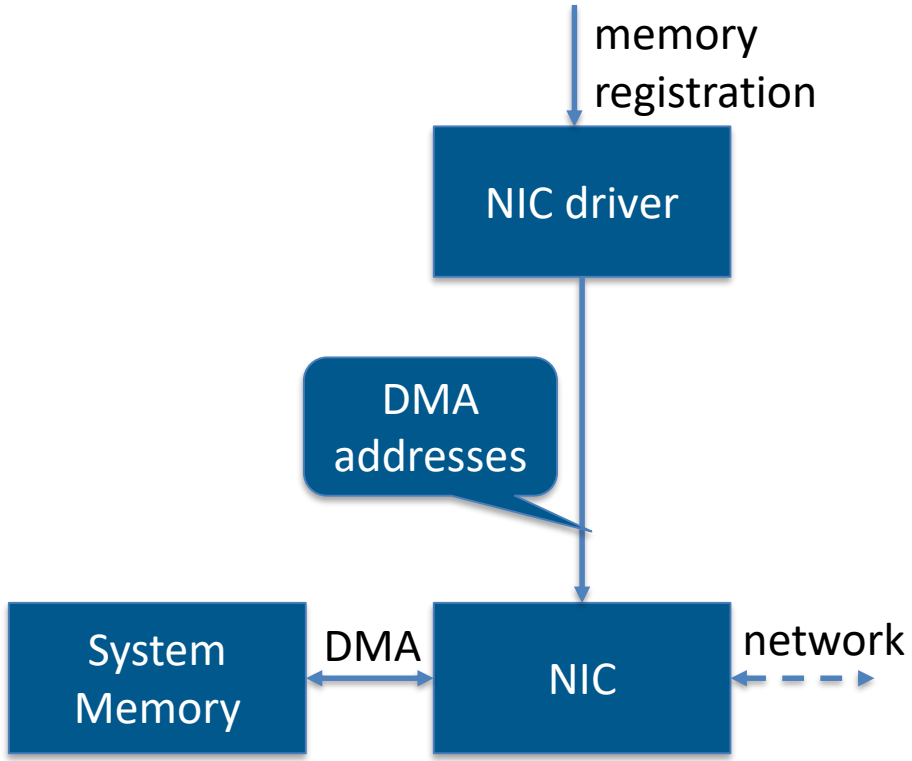
RDMA OVERVIEW

RDMA WITH SYSTEM MEMORY

- **RDMA is "DMA + network"**

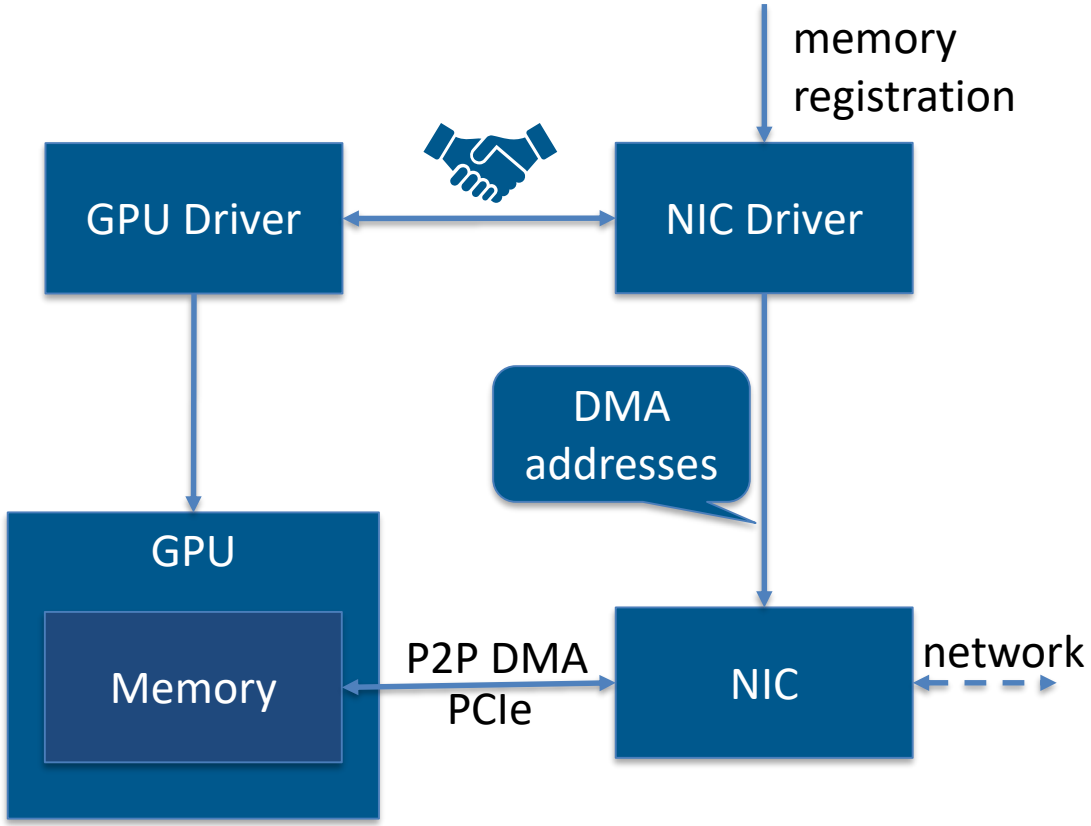
RDMA op	Initiator	Direction	Target
Write	DMA read	→	DMA write
Read	DMA write	←	DMA read

- **DMA requires proper setup of the memory**
  - Memory pages are "pinned"
  - Bus addresses are used
  - Usually done at the time of "memory registration"
  - For user space buffer in system memory
    - get_user_pages()
    - sg_alloc_table() / sg_set_page() / sg_next() / …
    - dma_map_sg()



RDMA WITH GPU MEMORY

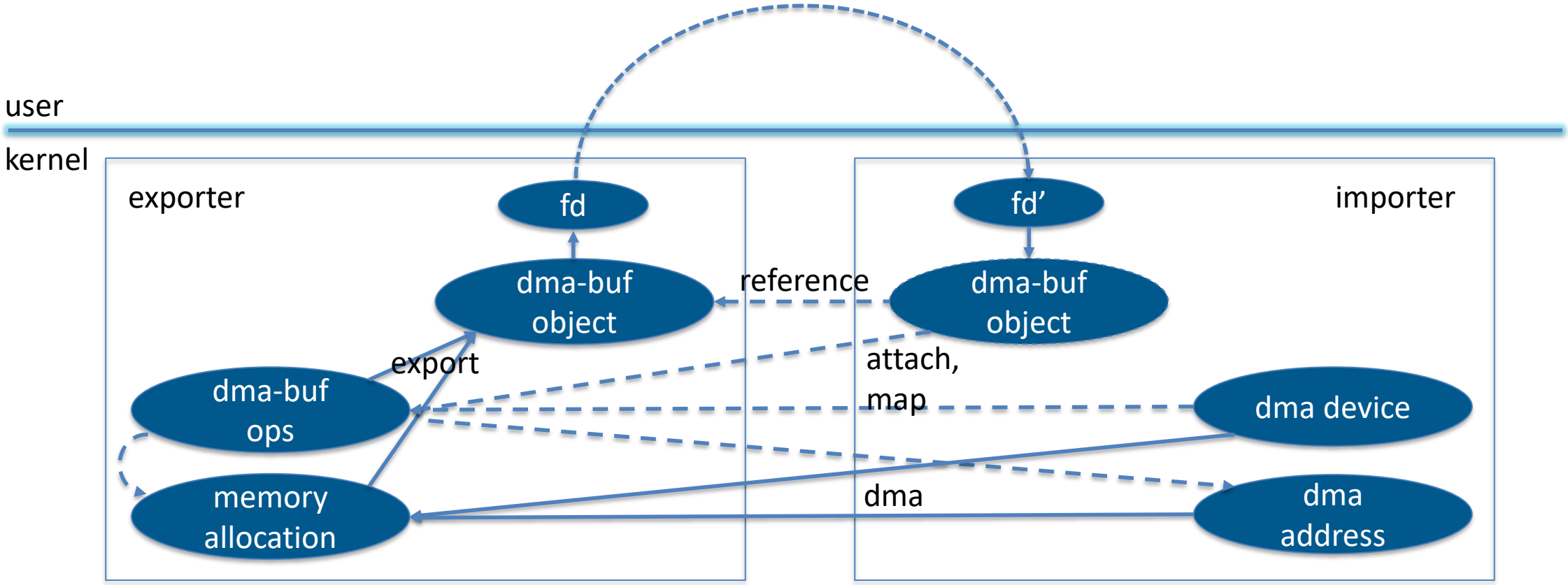
- **GPU memory is local**
  - The NIC driver can't pin the memory directly
  - The NIC driver doesn't know the DMA address
- **Cooperation between the NIC driver and the GPU driver is needed**
- **Peer-Direct from Mellanox**
  - Plug-in interface for kernel RDMA core
  - Each GPU driver provides a plug-in module
  - Plug-ins are queried one-by-one when memory is registered, until the ownership is claimed
  - Only available in MOFED
- **Can we have a non-proprietary upstream solution?**
  - Our proposal is to use dma-buf



DMA-BUF OVERVIEW

DMA-BUF OVERVIEW

- **Dma-buf is a standard mechanism in Linux kernel for sharing buffers between different device drivers**

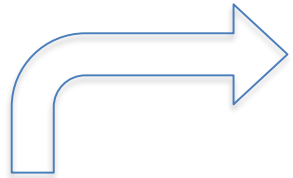


DMA-BUF API (EXPORTER)

- **Create a new dma-buf object**

```
struct dma_buf *dma_buf_export(const struct
dma_buf_export_info *exp_info);

    struct dma_buf_export_info {
        const char *exp_name;
        struct module *owner;
        const struct dma_buf_ops *ops;
        size_t size;
        int flags;
        struct dma_resv *resv;
        void *priv;
    };
```



```
struct dma_buf_ops {                    /* bold means mandatory */
        bool cache_sgt_mapping;
        bool dynamic_mapping;
        int (*attach)(struct dma_buf *, struct dma_buf_attachment *);
        void (*detach)(struct dma_buf *, struct dma_buf_attachment *);
        struct sg_table * (*map_dma_buf)(struct dma_buf_attachment *, enum
        dma_data_direction);
        void (*unmap_dma_buf)(struct dma_buf_attachment *, struct sg_table
        *, enum dma_data_direction);
        void (*release)(struct dma_buf *);
        int (*begin_cpu_access)(struct dma_buf *, enum dma_data_direction);
        int (*end_cpu_access)(struct dma_buf *, enum dma_data_direction);
        int (*mmap)(struct dma_buf *, struct vm_area_struct *vma);
        void *(*map)(struct dma_buf *, unsigned long);
        void (*unmap)(struct dma_buf *, unsigned long, void *);
        void *(*vmap)(struct dma_buf *);
        void (*vunmap)(struct dma_buf *, void *vaddr);
};
```

- **Associate with a file descriptor**

```
int dma_buf_fd(struct dma_buf *dmabuf, int flags);
```

DMA-BUF API (IMPORTER)

- **Retrieve dma-buf object**

  struct dma_buf ***dma_buf_get**(fd);

  void **dma_buf_put**(dma_buf);

- **Attach device to dma-buf**
  - *The exporter could check if the backing storage is accessible to dev*

  struct dma_buf_attachment ***dma_buf_attach**(dma_buf, dev);

  struct dma_buf_attachment ***dma_buf_dynamic_attach**(dma_buf, dev, flag);

  void **dma_buf_detach**(dmabuf, attach);

- **Map to DMA address**
  - *This is when the exporter need to determine the backing storage location and pin the pages*

  struct sg_table ***dma_buf_map_attachment**(attach, direction);

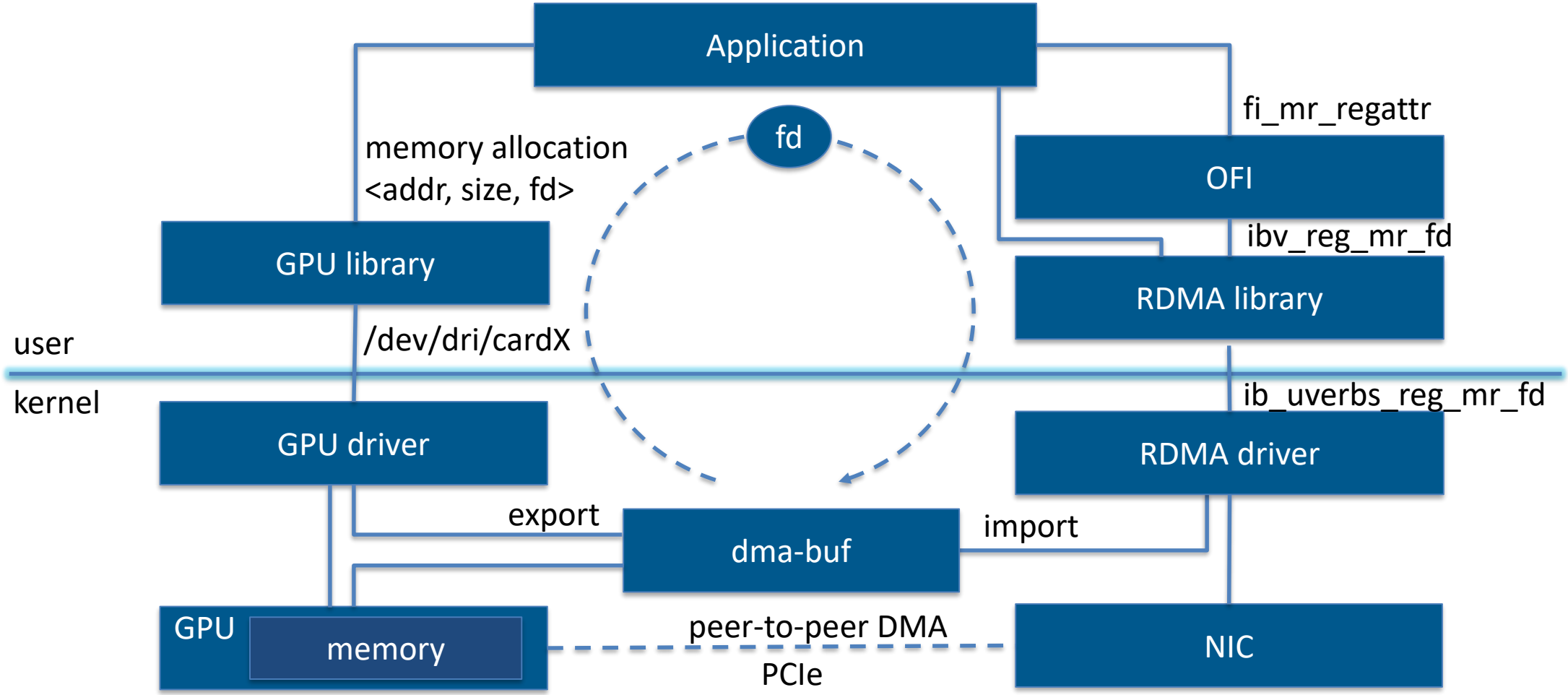
  void **dma_buf_unmap_attachment**(attach, sg_table, direction);

CPU access functions:

int dma_buf_begin_cpu_access();
int dma_buf_end_cpu_access();
void *dma_buf_kmap();
void dma_buf_kunmap();
int dma_buf_mmap();
void *dma_buf_vmap();
void dma_buf_vunmap();

USE DMA-BUF FOR GPU MEMORY RDMA

MEMORY REGISTRATION WORKFLOW



GPU SOFTWARE CHANGES

- **Dma-buf is supported by many existing GPU drivers**
  - As part of DRM / GEM / PRIME
  - Accessed by ioctl() over /dev/dri/card<n>, for example:

command	function
DRM_IOCTL_MODE_CREATE_DUMB	Allocate a “dumb” buffer
DRM_IOCTL_I915_GEM_CREATE	Allocate a “GEM” buffer
DRM_IOCTL_PRIME_HANDLE_TO_FD	Get the dma-buf file descriptor

  - Current GPU driver implementations may not be optimized for P2P access
    - On-going improvements. e.g. https://www.spinics.net/lists/amd-gfx/msg32469.html
- **User space library needs to provide an interface to retrieve the dma-buf fd**
  - As a property of allocated memory object (e.g. as the IPC handle)
  - Applications don’t want to call ioctl directly

RDMA DRIVER CHANGES

- **Core: support importing dma-buf as user memory via specialized ib_umem_get()**

```
struct ib_umem *
ib_umem_get(
        struct ib_udata *udata,
        unsigned long addr,
        size_t size, int access);
```

```
struct ib_umem *
ib_umem_dmabuf_get(
        struct ib_udata *udata,
        unsigned long addr,
        size_t size, int dmabuf_fd,
        int access);
```

- **Uverbs: define two new uverbs commands for memory registration**
  - IB_USER_VERBS_CMD_REG_MR_FD
  - IB_USER_VERBS_CMD_REREG_MR_FD
  - These two commands require two extra parameters when compared with the non-FD version:
    - fd_type: type of the file descriptor, allow future extension
    - fd: the file descriptor

RDMA DRIVER CHANGES (CONT)

- **Add two functions to the *ib_device* structure for interfacing with the vendor drivers**

```
struct ib_device {
        ……
        struct ib_mr * (*reg_user_mr_fd)( ……, int fd_type, int fd, int acc, …… );
        int (*rereg_user_mr_fd)( ……, int fd_type, int fd, int acc, …… );
};
```

- **Vendor RDMA drivers: implement the two functions**
  - Implementation is optional
    - Only needed if the vendor driver want to support dma-buf
    - Can choose to only support reg, but not rereg
    - Set ***ib_dev->dev.uverbs_cmd_mask accordingly***
  - Implementation is straightforward
    - Take the non-fd version, and replace ib_umem_get() with ib_umem_dmabuf_get()

RDMA LIBRARY CHANGES

- **Add two new functions to the Verbs API**

```
struct ibv_mr *ibv_reg_mr_fd (
        sruct ibv_pd *pd,
        void *addr,
        size_t length,
        enum ibv_mr_fd_type fd_type,
        int fd,
        int access );
```

```
int ibv_rereg_mr_fd (
        struct ibv_mr *mr,
        int flags,
        struct ibv_pd *pd,
        void *addr,
        size_t length,
        enum ibv_mr_fd_type fd_type,
        int fd,
        int access);
```

- Again, these functions have two extra parameters compared with the non-fd version

RDMA LIBRARY CHANGES (CONT)

- **Add two uverbs command functions to interface with the kernel driver**

```
int ibv_cmd_reg_mr_fd( ……, int fd_type, int fd, int access, ……);
int ibv_cmd_rereg_mr_fd( ……, int fd_type, int fd, int access, ……);
```

- **Add two functions to the *verbs_context_ops* structure for interfacing with vender libraries**

```
struct verbs_context_ops {
        ……
        struct ibv_mr *(*reg_mr_fd)( ……, enum ibv_mr_fd_type fd_type, int fd, int access );
        int (*rereg_mr_fd)( ……, enum ibv_mr_fd_type fd_type, int fd, int access );
};
```

- **Implement these two functions in the vender specific RDMA library (provider)**
  - Simply call the “ibv_cmd_” versions of these functions

OFI CHANGES

- **New fields in the fi_mr_attr structure allow fd being passed for memory registration**

```
struct fi_mr_attr {
        ……
        enum fi_hmem_iface iface;       /* The API used for memory allocation */
        union {
                uint64_t reserved;
                ……
                int fd;
        } device;
};
```

  - Must use fi_mr_regattr()
- **Providers need to recognize these fields and handle the registration properly**
  - Support is indicated by the FI_HMEM capability bit

STATUS AND FUTURE WORK

- **A software prototype has been implemented**
  - Based on upstream Linux kernel 5.6 and most recent user space rdma-core libraries
  - GPU: Intel GPUs that use the i915 driver
  - RDMA NIC: Mellanox ConnectX-4 EDR, upstream driver
- **Next steps**
  - Getting the RDMA driver changes into upstream Linux kernel
    - First RFC patch set was sent to the linux-rdma list and reviewed
    - Revised RFC patch set is being worked on
    - Depend on GPU drivers being able to pin device memory via dma-buf interface, which is not there yet at upstream
  - Getting the RDMA library changes into upstream rdma-core
  - Upstream the OFI changes

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THANK YOU

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