OPENFABRICS ALLIANCE

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USER MODE ETHERNET VERBS

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AGENDA

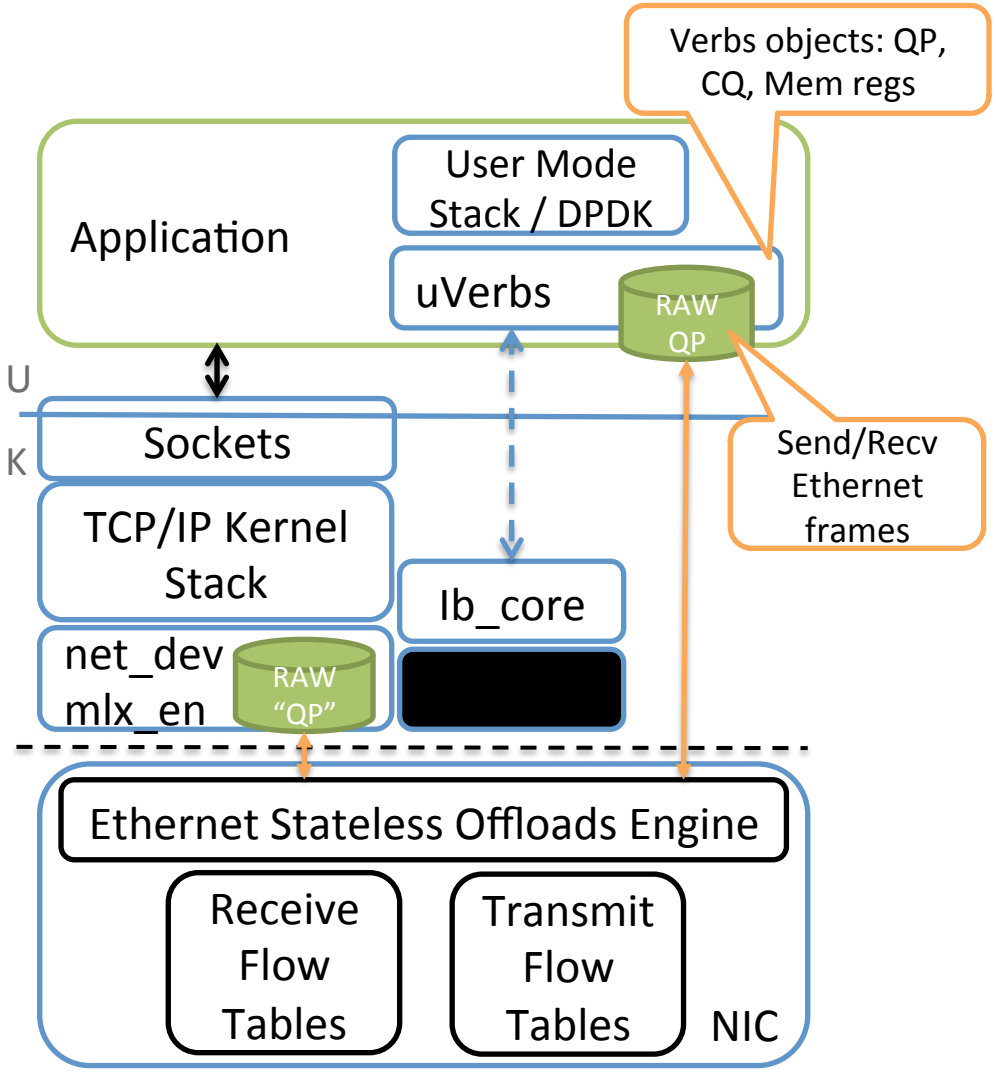
- Introduction
- Current status – The RAW ETH QP
- Receive Side Scaling
- L2 Tunneling stateless offloads
- Capturing
- Completion Queue – Support New Extensions
- User Mode Non-Privileged Access
- Conclusion

INTRODUCTION

- **Telecom, Web 2.0, Cloud & FSI high-end applications increase network requirements**
- **Would like to reduce operating systems overhead**
  - Data path direct User application to HW access APIs
  - Get high PPS rates, low latency, minimize cycle/byte and increased scalability
- **Transparently use standard TCP/UDP/IP protocols**
  - No need for proprietary protocol designs
  - Use existing rich HW protocol offload support
  - Can interoperate with traditional OS TCP/IP stack

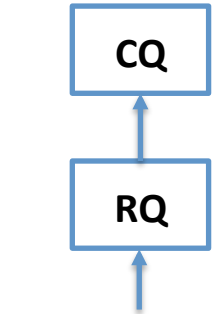
CURRENT STATUS – THE RAW ETH QP

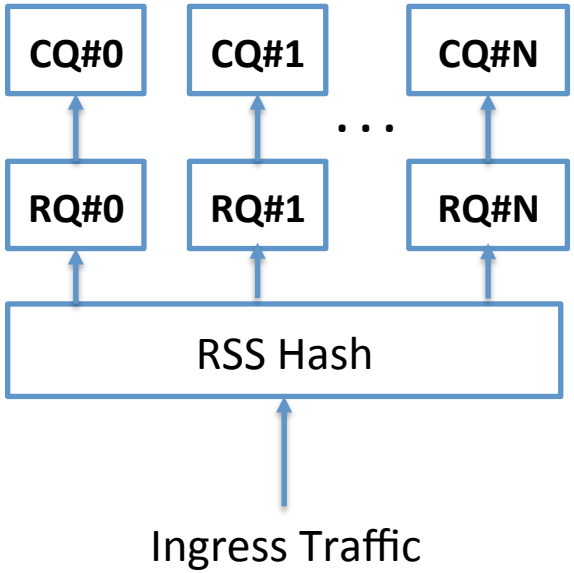
- **Ibv_qp type: RAW_ETH**
- **Use mature verbs objects**
  - QP, CQ, MR
- **Pair of send and receive queues**
  - Send queue to transmit raw packets - No implicit headers
  - Receive queue is steered according to flows classification
- **Stateless Offloads Engine**
  - Currently csum offload is supported
  - And Interrupt moderation (CQ moderation)
- **Require privileged user**
  - CAP_NET_RAW



RSS
Introduction

- **Receive Side Scaling (RSS) technology enables spreading incoming traffic to multiple receive queues**
- **Each receive queue is associated with a completion queue**
- **Completion Queues (CQ) are bound to a CPU core**
  - CQ is associated with interrupt vector and thus with CPU
    - For polling, user may run polling for each CQ from associated CPU
  - In NUMA systems, CQ may be allocated on close memory to associated CPU
- **Spreading the receive queues to different CPU cores allows spreading receive workload of incoming traffic**





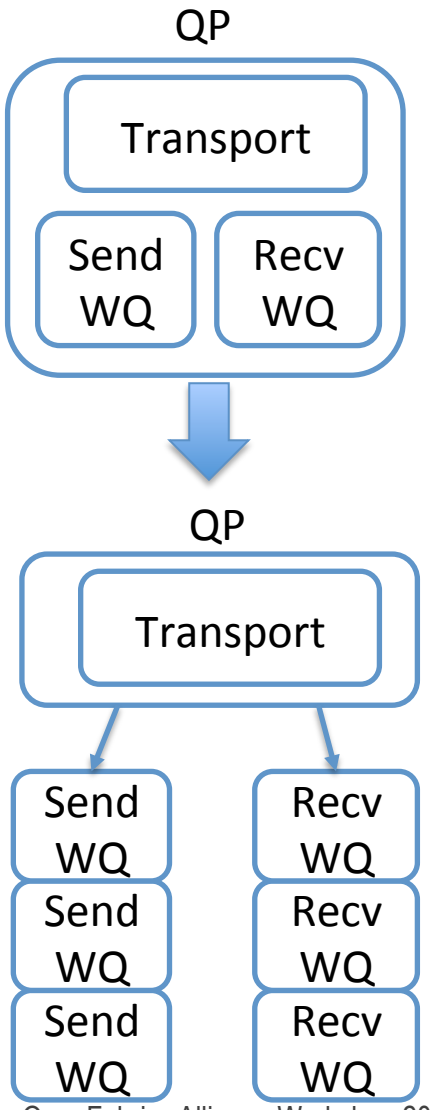
Classify first, distribute after

- **Begin with classification**
  - Using Steering (ibv_create_flow()) classify incoming traffic
  - Classification rules may be any of the packet L2/3/4 header attributes
    - e.g. TCP/UDP only traffic, IPv4 only traffic, ..
  - Classification result is transport object - QP
- **Continue with spreading**
  - Transport object (QPs) are responsible for spreading to the receive queues
  - QPs carry RSS spreading rules and receive queue indirection table
- **RQs are associated with CQ**
  - CQs are associated with CPU core
- **Different traffic types can be subject to different spreading**

RSS

Work Queue (WQ)

- **Typically QPs (Queued Pairs) are created with 3 elements**
  - Transmit and receive Transport
  - Receive Queue
    - Exception is QPs which are associated with SRQ
  - Send Queue
- **Extend verbs to support separate allocation of the above 3 elements**
  - Transport – ibv_qp with no RQ or SQ
    - Ibv_qp_type of IBV_QPT_RAW_ETH
      - Next will be UD QP type
    - New QP attribute: ibv_rx_hash_conf
  - Work Queue – ibv_wq
    - Can be of 2 types: IBV_RQ – Receive Queue and IBV_SQ
    - We'll start with IBV_RQ definition



RSS

Work Queue (WQ) – Cont.

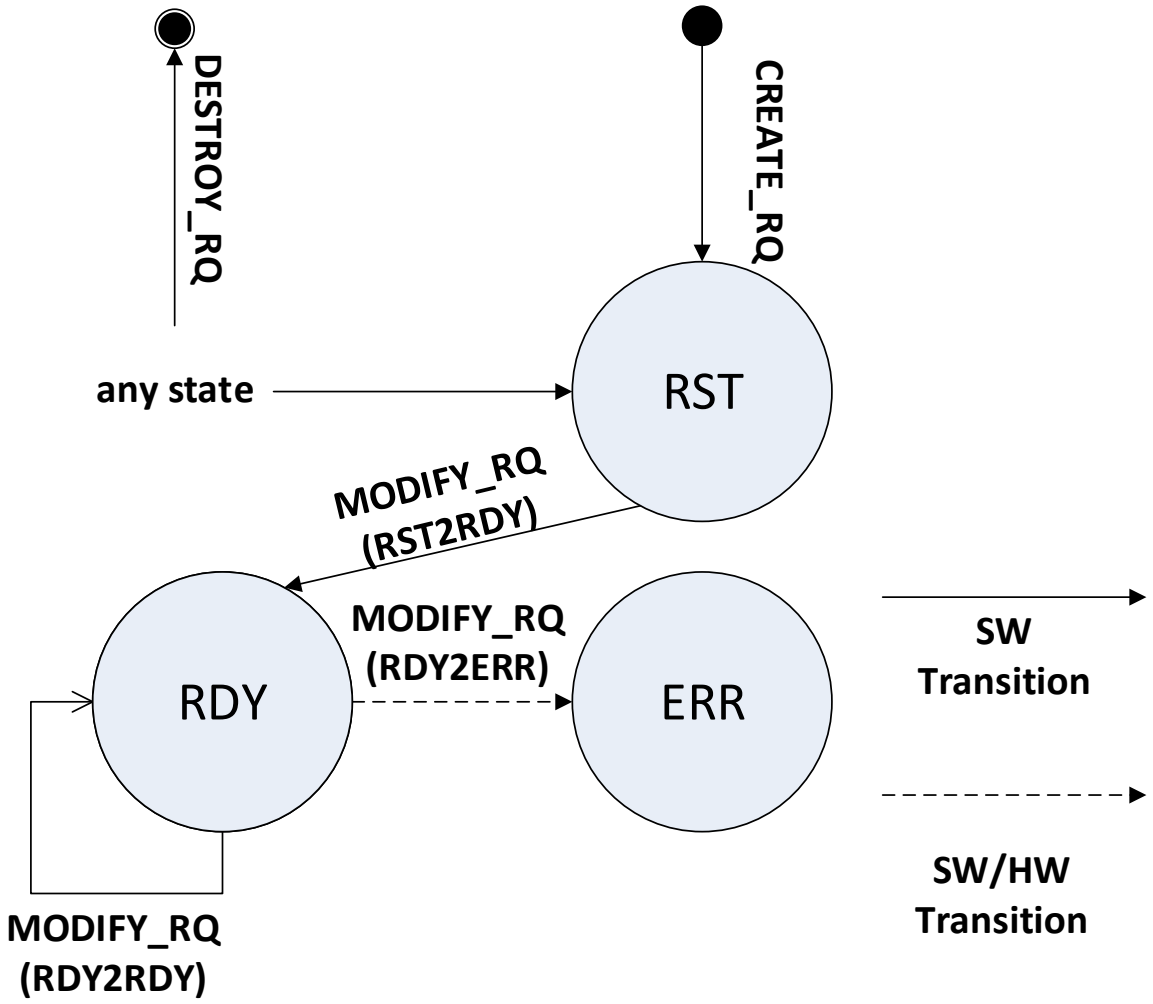
- **New object: Work Queue - ibv_wq**
- **Managed through following new calls:**
  - ibv_wq *ibv_create_wq(ibv_wq_init_attr)
  - ibv_modify_wq(ibv_wq , ibv_wq_attr)
  - ibv_destory_wq(ibv_wq)
  - ibv_post_wq_recv(ibv_wq, ibv_recv_wr)
- **Work Queues (ibv_wq) are associated with Completion Queue (ibv_cq)**
  - Multiple Work Queues may be mapped to same Completion Queue (many to one)

```
struct ibv_wq {
      struct ibv_context  *context;
      void                *wq_context;
      uint32_t            handle;
      struct    ibv_pd    *pd;
      struct    ibv_cq    *cq;
      /* SRQ handle if WQ is to be /
           associated with an SRQ, /
           otherwise NULL */
      struct    ibv_srq   *srq;
      uint32_t            wq_num;
      enum ibv_wq_state   state;
      enum ibv_wq_type    wq_type;
      uint32_t       comp_mask;
};
```

- **Work Queues of type Receive Queue (IBV_RQ) may share receive pull**
  - By associating many Work Queues to same Shared Receive Queue (the existing verbs ibv_srq object)
- **QP (ibv_qp) can be created without internal Send and Receive Queues and associated with external Work Queue (ibv_wq)**
- **QP can be associated with multiple Work Queues of type Receive Queue**
  - Through Receive Queue Indirection Table object

RSS

WQ of Type RQ – State Diagram



RSS

Receive Work Queue Indirection Table

- **New object: Receive Work Queue Indirection Table – ibv_rwq_ind_table**
- **Managed through following new calls:**
  - ibv_wq_ind_tbl *ibv_create_rwq_ind_table(ibv_rwq_ind_table_init_attr)
  - ibv_modify_rwq_ind_table(ibv_rwq_ind_table)
  - ibv_query_rwq_ind_table(ibv_rwq_ind_tbl, ibv_rwq_ind_table_attr)
  - ibv_destroy_rwq_ind_table(ibv_rwq_ind_tbl)
- **QPs may be associated with an RQ Indirection Table**
- **Multiple QPs may be associated with same RQ Indirection Table**

```
struct ibv_rwq_ind_table {
     struct ibv_context  *context;
     uint32_t            handle;
     int             ind_tbl_num;
     uint32_t        comp_mask;
};

/*
 * Receive Work Queue Indirection Table
attributes
*/
struct ibv_rwq_ind_table_init_attr {
     uint32_t        log_rwq_ind_tbl_size;
     struct ibv_wq   **rwq_ind_tbl;
     uint32_t        comp_mask;
};

/*
 * Receive Work Queue Indirection Table
attributes
*/
struct ibv_rwq_ind_table_attr {
     uint32_t        attr_mask;
     uint32_t        log_rwq_ind_tbl_size;
     struct ibv_wq   **rwq_ind_tbl;
     uint32_t        comp_mask;
};
```

RSS

Transport Object (QP)

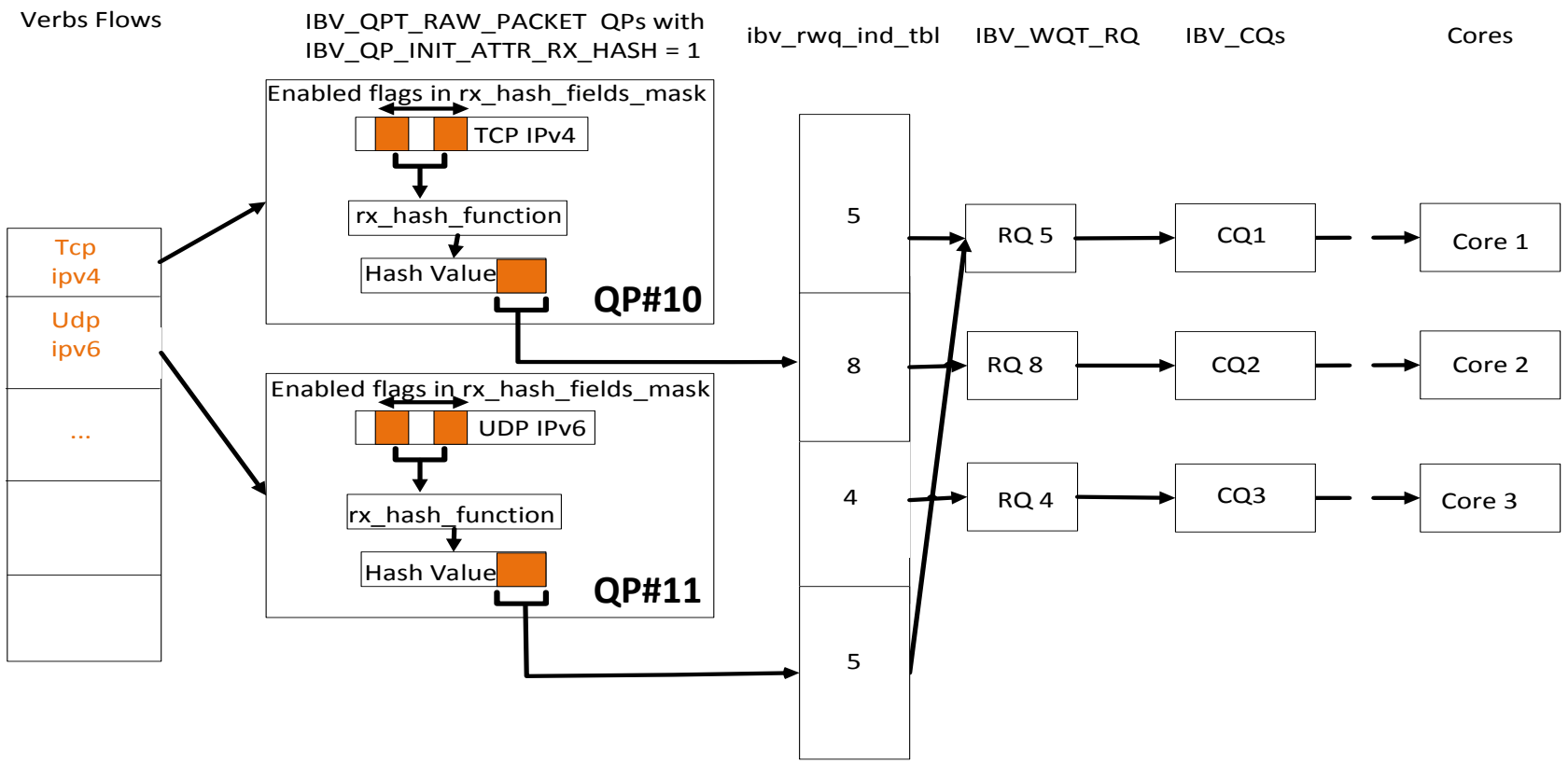
- **"RSS" QP**
  - QP attributes (ibv_qp_attr) now include RSS hash configuration attributes (ibv_rx_hash_conf)
  - QP is Stateless
  - QP's Send and Receive WQs parameters are invalid - QP has no internal work queues
  - Use ibv_post_wq_recv instead of ibv_post_recv
  - QP is connected to RQ Indirection Table
- **On Receive, traffic is steered to the QP according to existing steering API**
  - Ibv_create_flow()
- **Following, matching RQ is chosen according to QPs hash calculation**

```
struct ibv_rx_hash_conf {
      /* enum ibv_rx_hash_fnction */
      uint8_t    rx_hash_function;
      /* valid only for Toeplitz */
      uint8_t   *rx_hash_key;
      /* enum ibv_rx_hash_fields */
      uint64_t   rx_hash_fields_mask;
      struct ibv_rwq_ind_table   *rwq_ind_tbl;
};
/*
 RX Hash Function.
*/
enum ibv_rx_hash_function_flags {
      IBV_RX_HASH_FUNC_TOEPLTIZ   = 1 << 0,
      IBV_RX_HASH_FUNC_XOR        = 1 << 1
};
/*
 Field represented by the flag will be
 used in RSS Hash calculation.
*/
enum ibv_rx_hash_fields {
      IBV_RX_HASH_SRC_IPV4        = 1 << 0,
      IBV_RX_HASH_DST_IPV4        = 1 << 1,
      IBV_RX_HASH_SRC_IPV6        = 1 << 2,
      IBV_RX_HASH_DST_IPV6        = 1 << 3,
      IBV_RX_HASH_SRC_PORT_TCP    = 1 << 4,
      IBV_RX_HASH_DST_PORT_TCP    = 1 << 5,
      IBV_RX_HASH_SRC_PORT_UDP    = 1 << 6,
      IBV_RX_HASH_DST_PORT_UDP    = 1 << 7
};
```

RSS
Flow Diagram

Verbs Steering Classifies the traffic

IBV_QPT_RAW_PACKET QPs distributes traffic type between RQs/Cores



RSS

Next

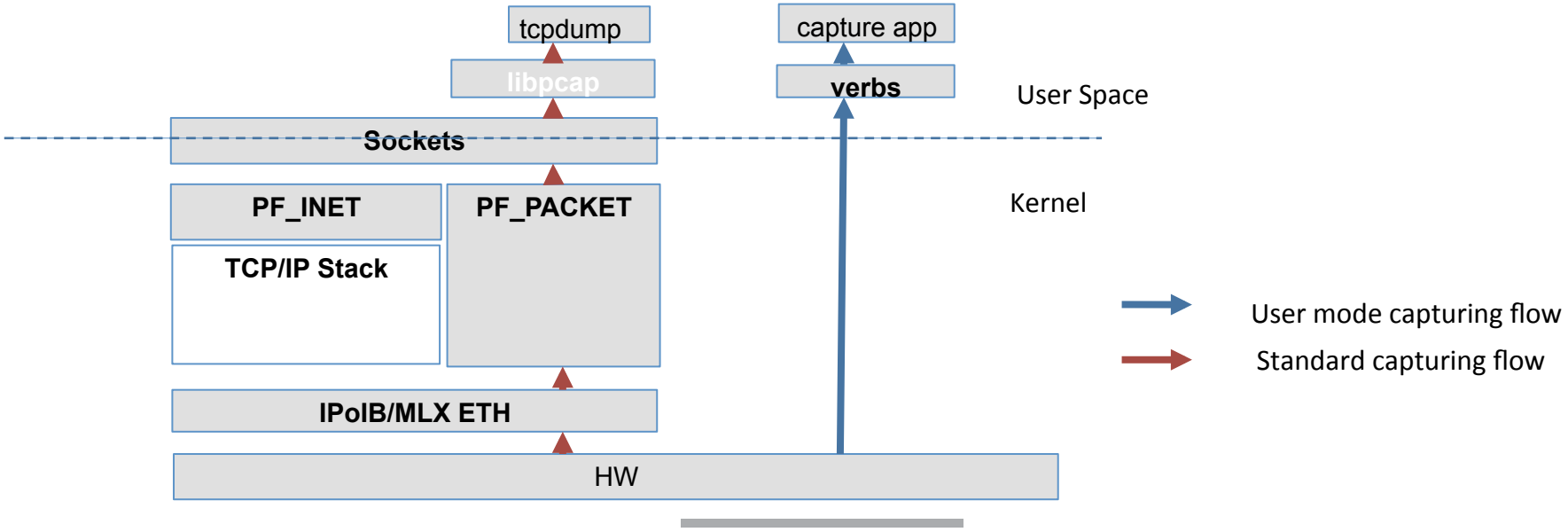
- **IPoIB UD QP type**
  - "RSS" UD QP is connected to RQ Indirection Table
  - RSS UD QP to continue to manage UD transport attributes: pkey, qkey checks…
  - Single wire QPN for all getting to all the QPs Receive Queues
- **Transmit Side Scaling (TSS)**
  - As in RSS, QP is stateless, Send and Receive work queues attributes are invalide
  - Use ibv_post_wq_send instead of ibv_post_send
  - For IPoIB UD QP:
    - Manage UD transport properties: pkey, qkey…
    - Use single source QPN in DETH wire protocol header for all Send WQ which is the "TSS" UD QP
  - The same QP may be used for both "RSS" and "TSS" operations

L2 TUNNELING

- **Tunneling technologies like VXLAN, NVGRE, GENEVE were introduced for solving cloud scalability and security challenges**
- **Require extensions of traditional NIC stateless offloads**
  - TX and RX inner headers checksum
    - ibv_qp_attr to control inner csum offload
    - Ibv_send_wr, ibv_wc to request and report inner csum
  - Inner TCP Segmentation and De-segmentation (LSO/LRO)
    - ibv_send_wr to support inner MSS settings
  - Outer and inner Ethernet header VLAN insertion and stripping
    - Ibv_qp_attr to control VLAN insert/strip
    - Ibv_send_wr to indicate VLAN
    - Ibv_wc to report strip VLAN
  - Steering to QP according to outer and inner headers attributes
    - Ibv_create_flow(ibv_flow_attr) to support inner headers
  - Perform RSS based on inner or on outer header attributes
    - Ibv_qp_attr.ibv_rx_hash_conf to support inner header attributes
  - Inner packet parsing and reporting its properties in Completion Queue Entry (CQE)
    - Ibv_wc to support inner headers extraction

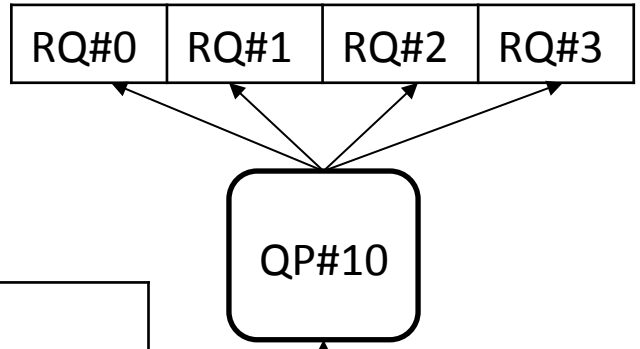
CAPTURING

- **Support standard Capturing interfaces and solutions**
  - User mode Ethernet traffic (OS Bypass traffic) is capture-able like traditional TCP/IP stack traffic
  - For Linux: standard PF_PACKET RAW Socket libpcap support, ie. utilities that use libpcap are supported: tcpdump, wireshark, …
  - Windows: Microsoft Message Analyzer (MMA)
- **Both TX and RX traffic**
- **Applicable for both ETH and RDMA traffic capturing**



CAPTURING
OS Bypass Capture App

- **User mode OS bypass capturing application through Verbs API**
  - Through ibv_create_flow() plus indicating sniffer flag
  - Classify requested captured traffic
  - Steer to QP. Can be “RSS” QP



Sniffer Flow Table

Priority	Classification	Direction	Action
1	MAC+VLAN	TX+RX	QP#10 SNIFF
..			

COMPLETION QUEUE (CQ)

New Extension Support - Introduction

- **Extending Verbs Support for user mode Ethernet requires growing the Work Completion (ibv_wc)**
- **More and more attributes are added to ibv_wc**
  - Completion time stamp
  - Stripped VLAN
  - Checksum and RSS hash result
  - Tunneling inner headers information
  - ..
- **Completion Queue polling (ibv_poll_cq(ibv_wc*)) is critical data path operation**
- **Growing ibv_wc size will result in performance hit**
  - Increased cache misses
  - Redundant extra copies of per vendor HW completion memory to SW completion memory (ibv_wc)
- ***A single completion data for all use cases is obsolete***

COMPLETION QUEUE (CQ)

New Extension Support - Verbs

- **Requirements**
  - Completion (CQE) attribute read according to application needs
  - Per vendor optimizations for each read access
  - Batch read of multiple Completions (CQE) followed by single read pointer update
- **ibv_cq is extended to include function pointers for completion handling**
  - Object oriented approach – no need to over populate general verbs function namespace
  - Methods will support extracting each completion attribute
    - So each app can extract only relevant attributes
  - Each verbs provider (vendor) will build it's extraction method
  - Additionally a single method will be provided for extracting mostly used attributes (opcode, status, ..)
- **Batch read support**
  - Ibv_begin_poll(ibv_cq*) – Grab CQ lock
  - Ibv_next_poll(ibv_cq*) – Advance CQ read pointer
  - Ibv_end_poll(ibv_cq*) – Update the provider with CQ read pointer (typically doorbell to HW)

```
struct ibv_cq_ex {
  /* legacy ibv_cq fields */
  ibv_cq cq;
  int comp_mask;

  /* CQ management methods */
  int (*begin_poll_ex)(struct ibv_cq_ex *cq);
  int (*next_poll_ex)(struct ibv_cq_ex *cq);
  void (*end_poll_ex)(struct ibv_cq_ex *cq);

  /* Work Completion per attribure read methods */
  ibv_wc  *(*ibv_read_wc)(struct ibv_cq_ex *cq);
  int     (*read_result)(ibv_wc_opcode *opcode,
     enum ibv_wc_status* status);
  uint64 (*read_time_stamp)(struct ibv_cq_ex *cq);
  field1_t (*read_field1)(struct ibv_cq_ex *cq);
  field2_t (*read_field2)(struct ibv_cq_ex *cq);
  ..
};
```

RAW ETH QP PRIVILIGES

Under Definition

- **RAW ETH QP allows app to build it's own L2/3/4 headers**
  - Alike SOCK_RAW socket() type
- **Caller to ibv_create_qp() with QP type of RAW_ETH must have CAP_NET_RAW privileges**
  - Alike SOCK_RAW socket() type
- **Support non-privileged user - L2/3/4 headers must be controlled by OS**
- **Option I:**
  - Add new QP types: RAW_ETH_UDP, RAW_ETH_TCP
  - Use ibv_ah for RAW ETH QP
  - Add d.IP indication to ibv_ah
  - On ibv_create_ah()ib_core will perform route and address resolution to determine source I/f and corresponding s.MAC, s.IP and d.MAC.
  - L2/L3 header info will be cached in ibv_ah and registered for updates in case neigh is updated
    - Perform period updates of kernel dst neigh aging timers
    - HW is configured to enforce headers checks
- **Option II:**
  - Stay with single QP Type: RAW_ETH
  - App still build L2/3/4 headers itself
  - HW is configured to enforce headers checks on allowed L2/3 addresses and L4 ports per QP
  - Allowed addresses, ports may be configured though ibv_create_qp and/or ibv_create_flow()
- **Continue supporting RAW access for privileged users**

CONCLUSION

- **Verbs API infrastructure is a robust and efficient API**
- **Generic object model to expend to new I/O offloads**
- **Control and data path infrastructure**
  - Use OS services for control path and allow bypass for data path
  - Can answer performance requirements for both high PPS, BW and low latency
- **Extendable in backward and forward compatible manner through Verbs extensions**

Great platform to expand user mode Ethernet programming

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