High Frequency Trading and other Workloads on Advanced NICs

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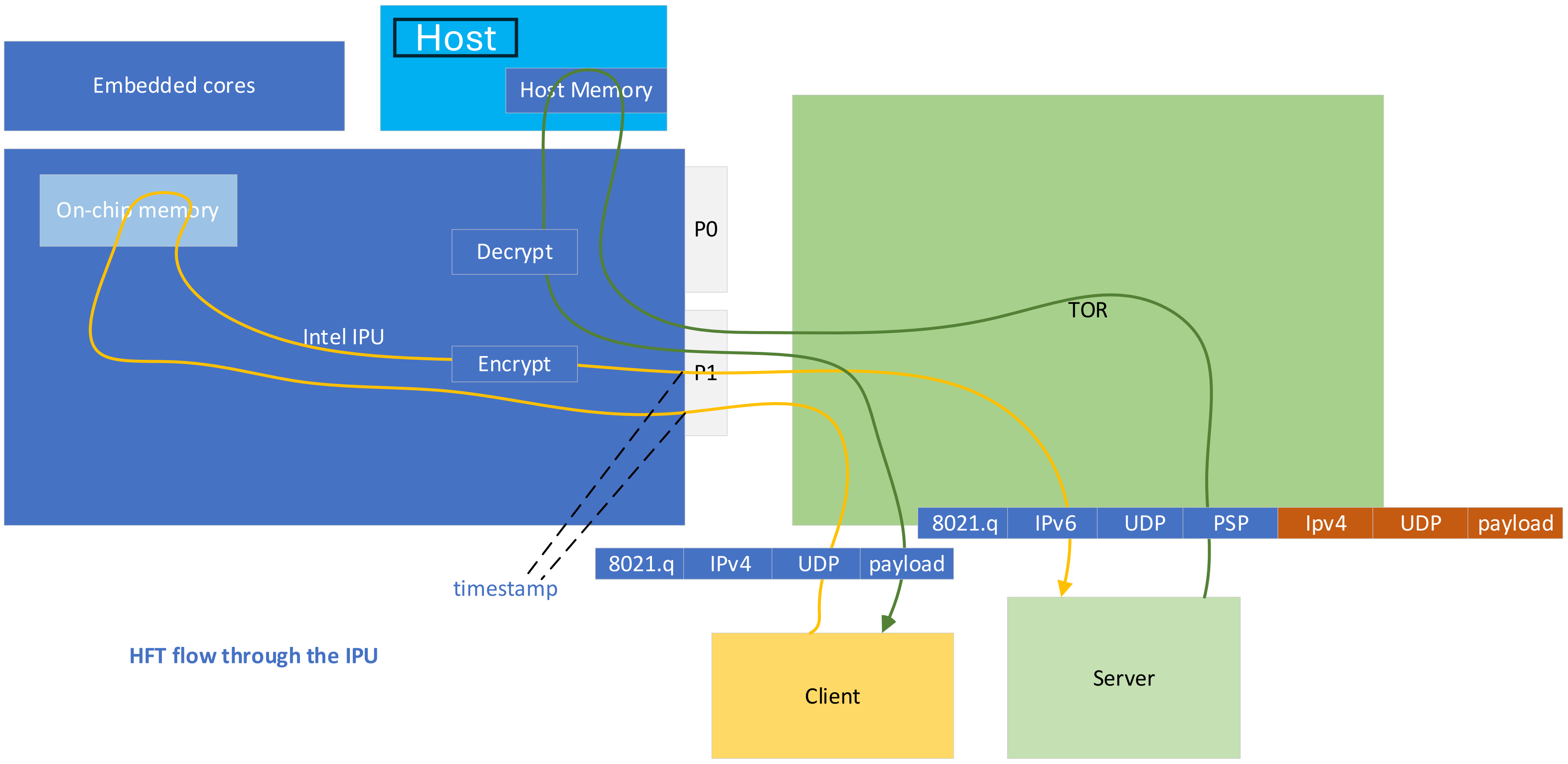
Agenda

- HFT Requirements
- 3 Use cases
  - Low latency, low jitter dedicated TC in HW with other offloads for HFT
  - Per flow Fixed Delay
  - EDT (Earliest Departure Time) using Fair Queue Scheduling offload onto the NIC

1. HFT (High frequency trading) Workload NIC requirements

- Very low Latency
- Very little deviation in latency per packet per flow (Very tight tail latency, low jitter)
- Low latency and High Priority Traffic class in Device to separate the HFT flows from rest of the flows
- Time synchronization between system and Network Device (PTM and PTP)
- Flow Identification and flow scheduling/fixed delay etc (EDT offload on devices through linux kernel.)
- Inline Crypto offload
- Multicast replication

HFT: Low latency, High Priority TC



HFT flow through the IPU

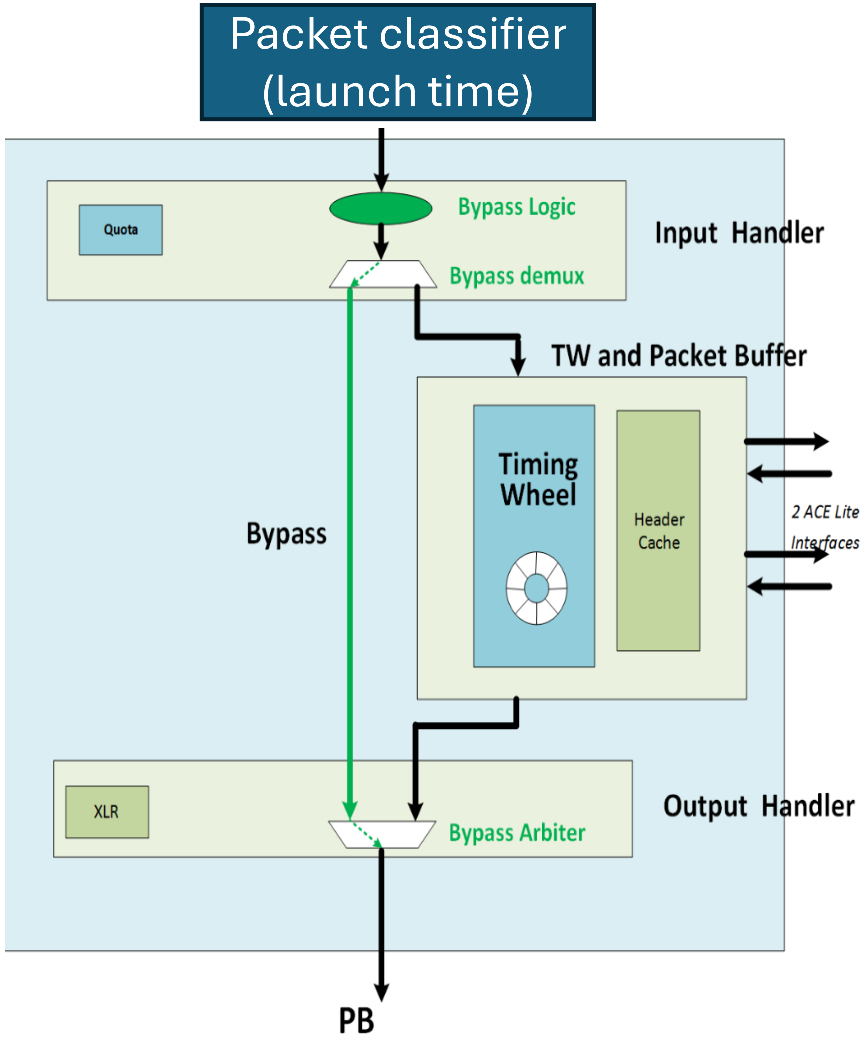
HFT flow through the NIC

- Flows to be identified belonging to low latency TC and then a different ordering domain selected for the low latency flows so that they are not Head of line blocked by the regular flows.
- HW Port 2 Port queue support
- Queue and the buffers for low latency are mapped on OCM (ARM) and so they avoid PCIE latency and jitter.
- PTP helps in making sure, the packets get timestamped at ingress and egress to monitor the packet latency needed for user logs.

2. Per flow fixed delay HW offload

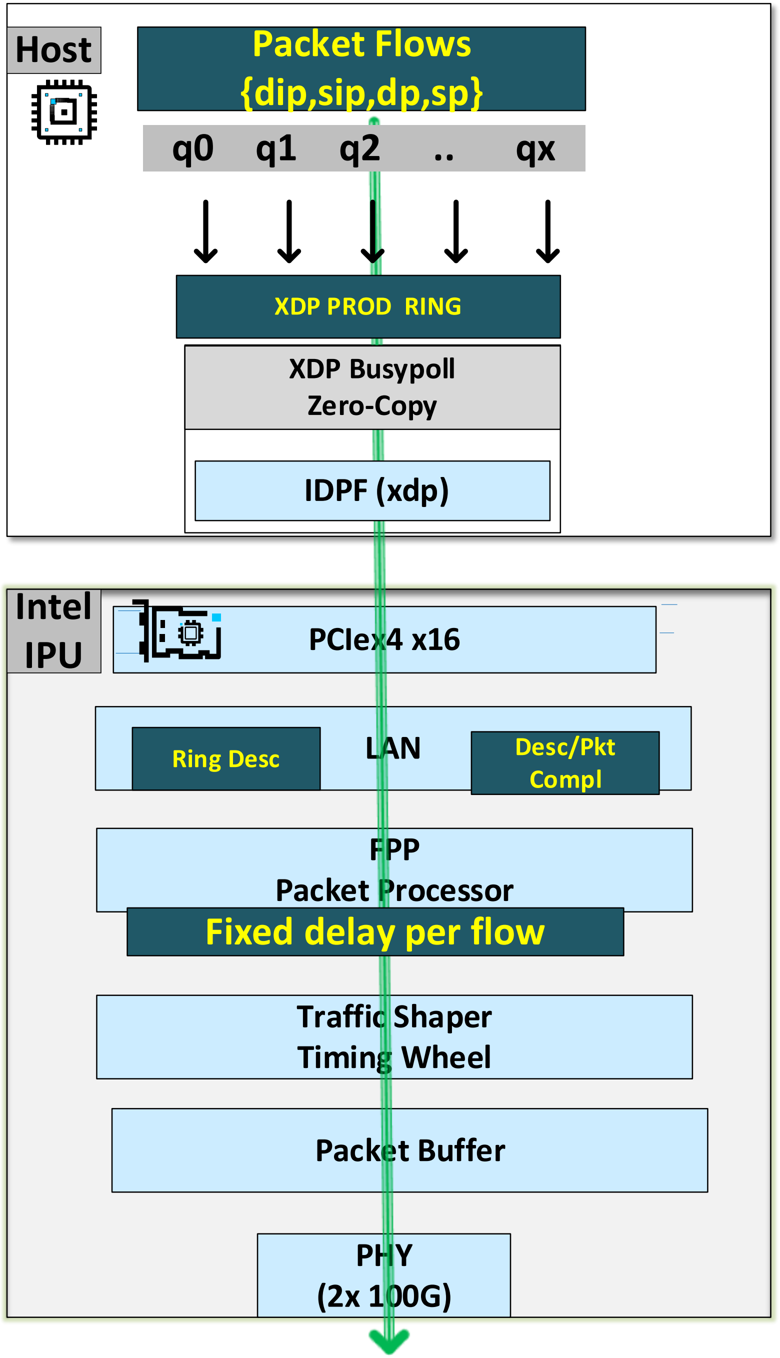
- Helps with scaling to large number of flows and achieving line rate, requires the device to handle large number of inflight packets waiting to be scheduled.
- Flow identification
- Packet timestamping and delay add using ALU operations
- Packet delays achieved using Timing Wheel in HW

Timing Wheel : HW Design for flow pacing



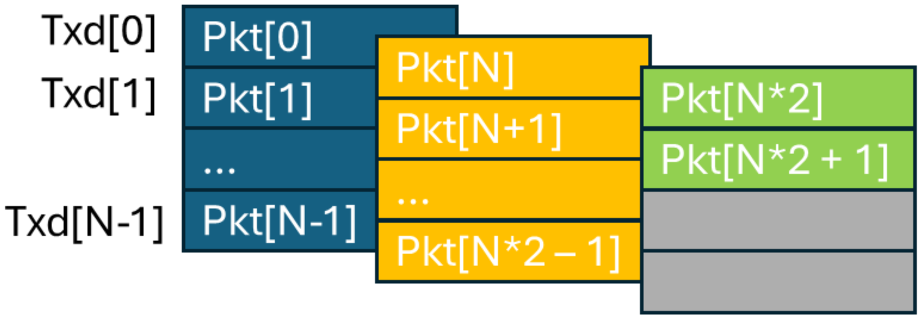
Fixed delay packet flow

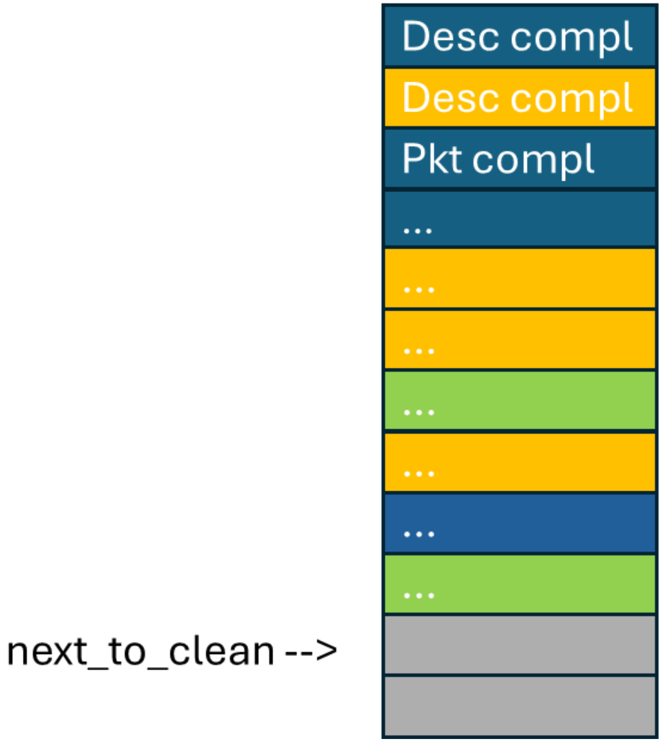
- Flexible packet processor identifies packet flow and adds fixed delay per packet flow.
- Packet shaper timing wheel schedules and buffers delayed packets in HW.
- AF XDP busy-poll with zero copy applications.



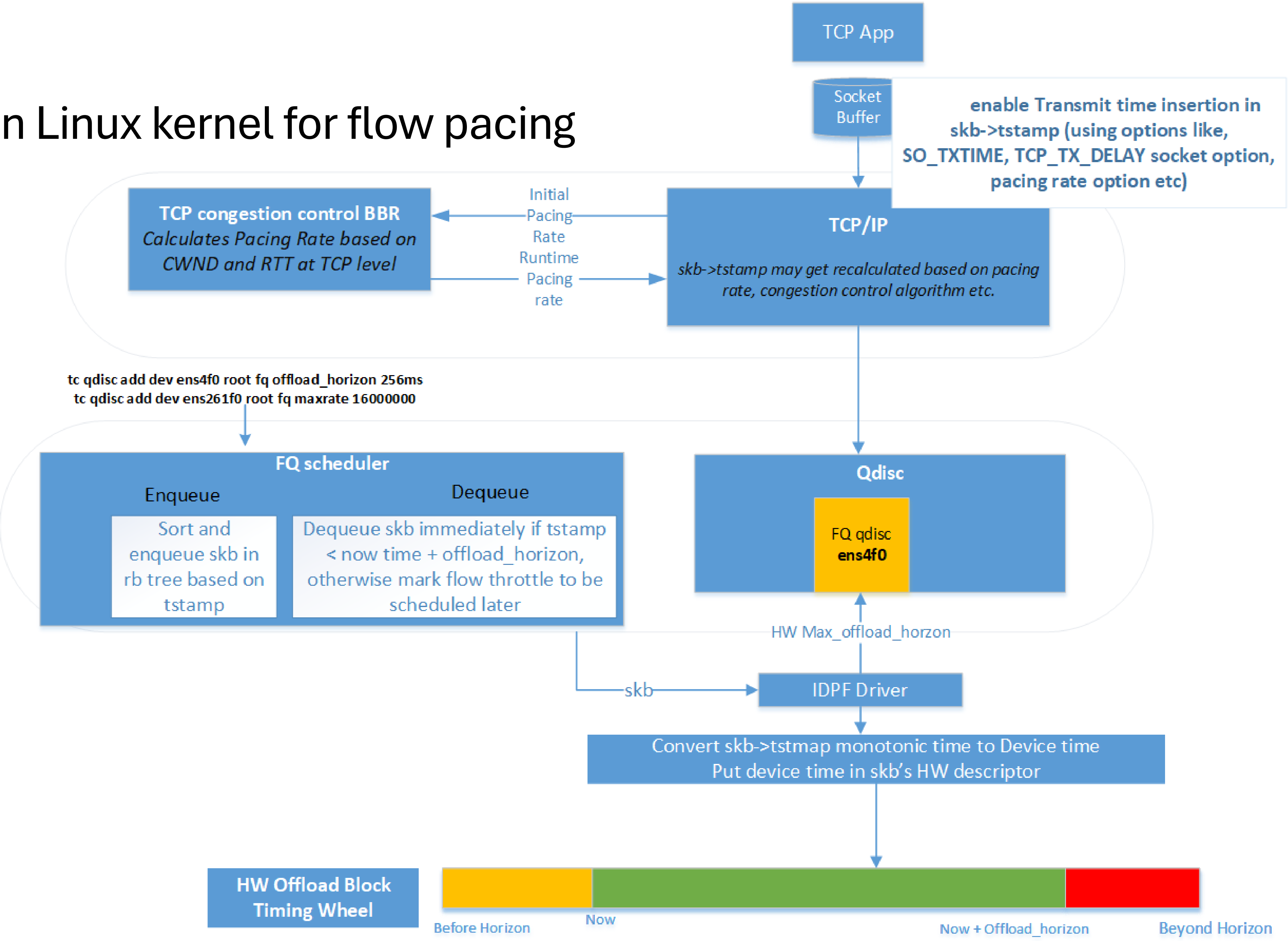
Enabling More than TxQ[size] AF_XDP Packets in Flight

- Completion queue is used to process descriptor completions and buffer completions
  - Descriptor completions tell driver that HW is done reading the descriptors
  - Packet completions tell driver the HW has DMA'ed the packet data (essentially when the packet goes on the wire)
- With this decoupling, driver can reuse the Tx queue descriptors to send more packets while waiting for the paced packet buffer completions
  - Number of completion queue descriptors dictates how many times TxQ can be reused before TX is halted
    - Track pending completions and stop TxQ if there are too many in flight
- Packet completions can arrive in any order (e.g. if different flows are paced at different intervals)
  - Use new API to mark individual XSK frames as completed
    `xsk_tx_complete_ooo(struct xsk_buff_pool *pool, u64 addr)`
- To look for Descriptor completion when posting new tx packets
  `bool xsk_tx_peek_desc_ooo(struct xsk_buff_pool *pool, struct xdp_desc *desc);`





3. EDT enabling in Linux kernel for flow pacing



EDT enabling in Linux kernel for flow pacing

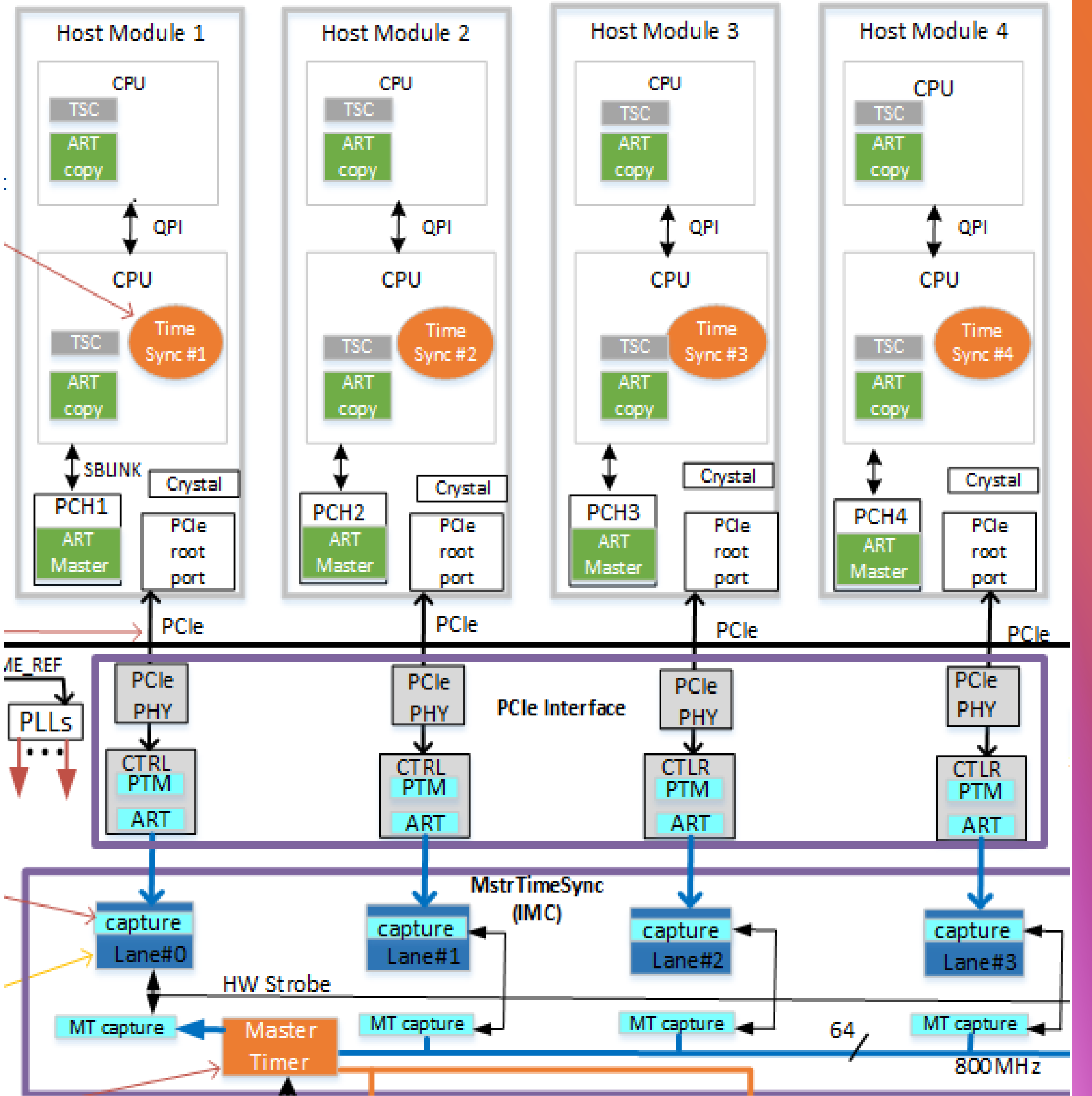
- FQ Qdisc TC Offload (Partial changes are already in kernel)
- IDPF Driver exposes HW capability Maximum offload Horizon to FQ qdisc
- Various ways to insert timestamp in skb, congestion control algorithm, pacing rate, SO_MAX_PACING_RATE and TCP_TX_DELAY socket options
- FQ qdisc dequeues all packets that fits within offload horizon window and rest are throttled to be dequeued later.
- IDPF driver converts skb->tstamp monotonic time to device time. Device time is put into skb descriptor to be used by Timing Wheel HW block
- TCP, FQ and TCP congestion algorithm uses monotonic timer clock for timestamp instead of Real timer clock
- TBD: PTP hooks are used to sync Device timer and Real timer. In future, instead of converting monotonic time to device time (very expensive), a handler will be added in IDPF driver to convert monotonic time to real time, assuming PTP crosstimestamping, PTM etc has synced device and real clock
- PTM PCIe capability provides higher accuracy and low latency for time synchronization.

Offload benefits

- Lower CPU utilization or
- Higher Throughput

PTM (PCIe Precision Time Measurement protocol)

- PTM is periodically initiated by HW
- Host TSC/ ART copy is sent over PCIe
- ART copy and Device time are captured together upon PCIe strobe. That results in great accuracy of both Timer's snapshot at a moment
- PTP SW stack in absence of PTM does not show accuracy, as taking Device time and System time cannot be done in same snapshot.
- Linux PTP Cross-timestamp framework is used to capture ART copy and device timer. Using delta b/w ART copy and device time, Real time clock can be adjusted.
- Prior to PTM, SW mechanisms were used, and the accuracy was in the order of ~1 microsec vs with PTM its ~400 nanoseconds.



Multicast replication

Mirror all incoming multicast packets on eth0 to eth1 interface

```
# tc qdisc add dev eth0 handle ffff: clsact
# tc filter add dev eth0 ingress protocol ip  prior 1\
        flower src_mac 49:aa:bb:cc:dd:ee  \
        action mirred egress mirror dev eth1
```

https://man7.org/linux/man-pages/man8/tc-mirred.8.html

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