libeventdev: Event driven programming model framework for DPDK

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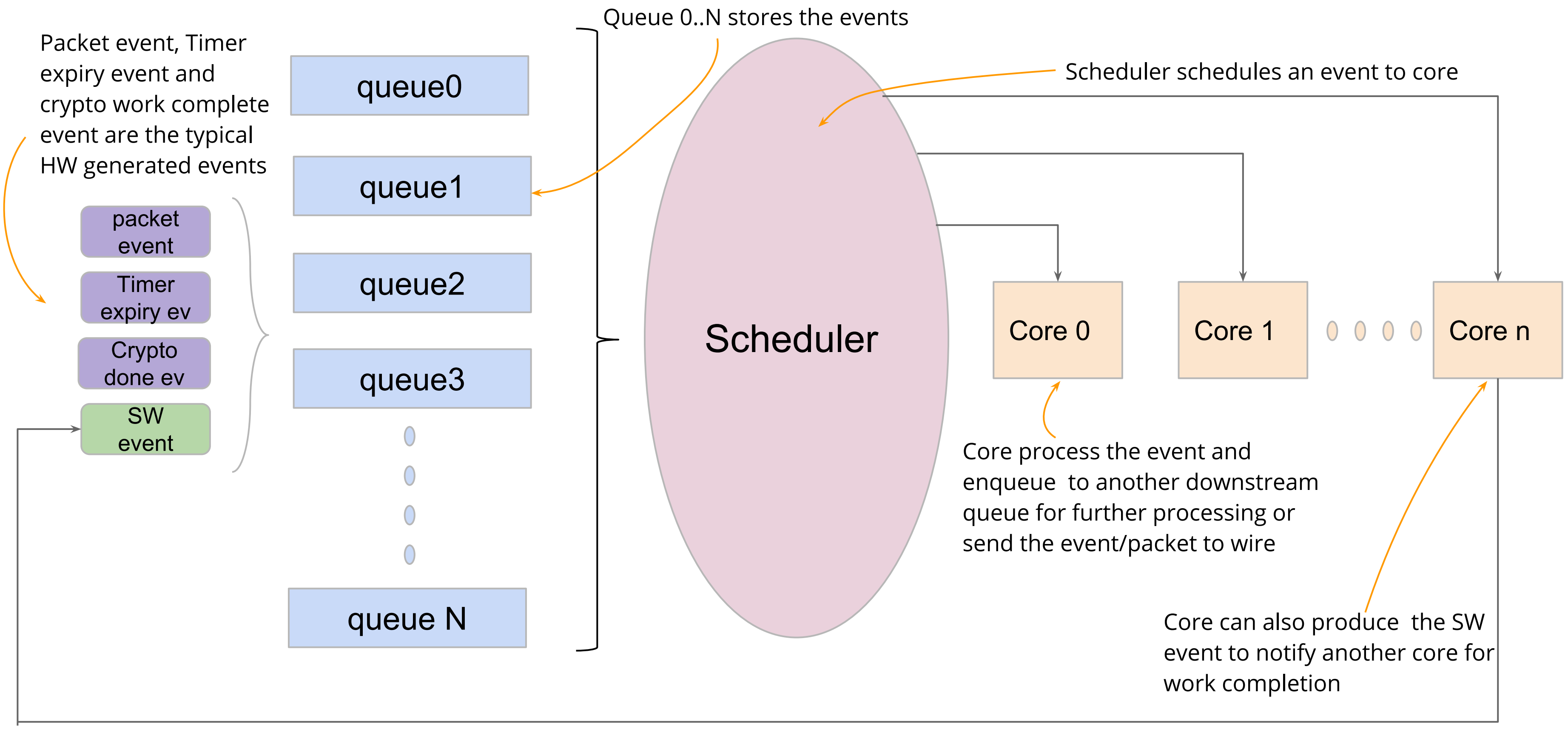
Agenda

- Event driven programming model concepts from data plane perspective
- Characteristics of HW based event manager devices
- libeventdev
- Example use case - Simple IPSec outbound processing
- Benefits of event driven programming model

Event driven programming model - Concepts

- Event is an *asynchronous* notification from HW/SW to CPU core
- Typical examples of events in dataplane are
  - Packets from ethernet device
  - Crypto work completion notification from Crypto HW
  - Timer expiry notification from Timer HW
  - CPU generates an event to notify another CPU(used in pipeline mode)
- Event driven programming is a programming paradigm in which flow of the program is determined by events

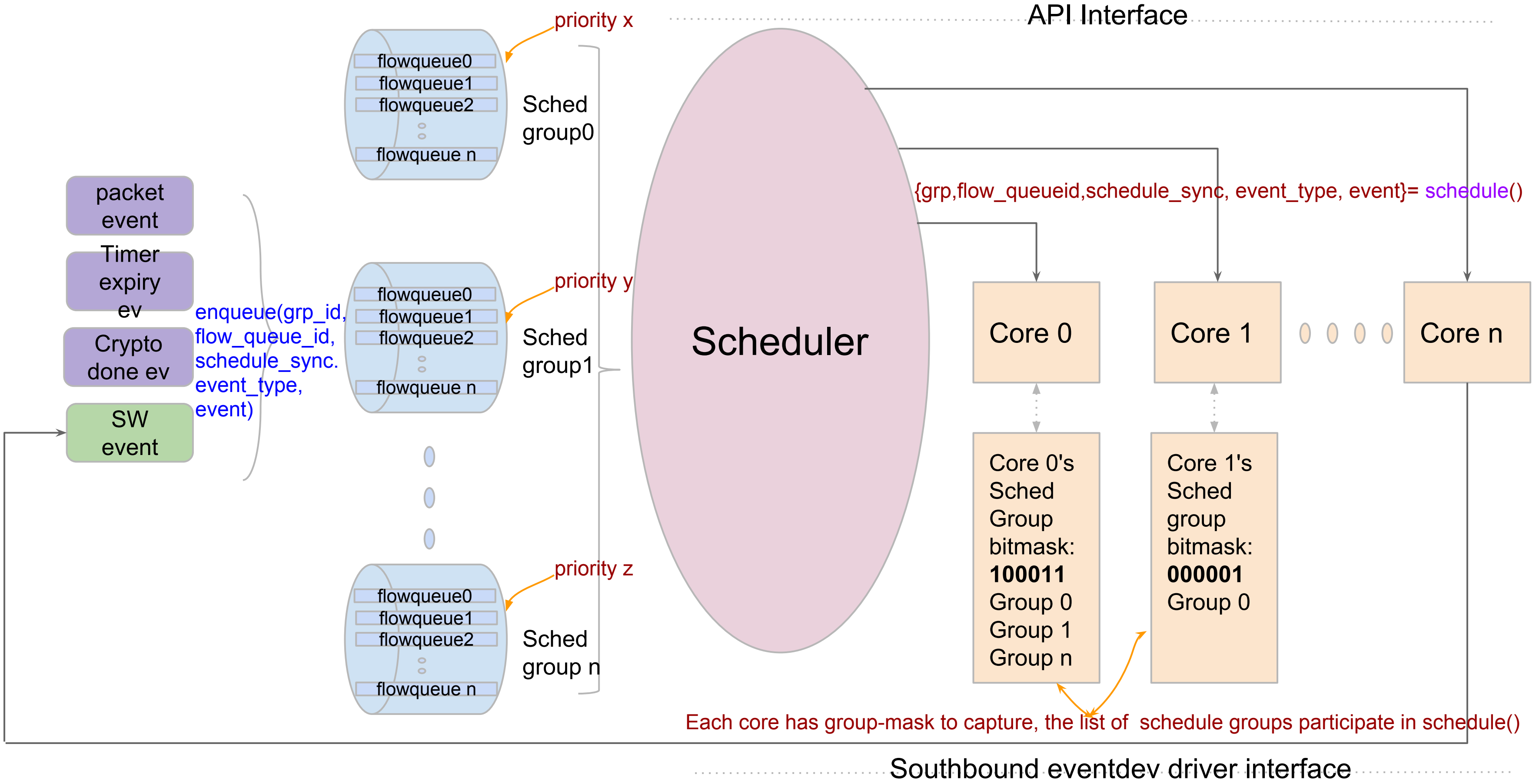
Event driven programming model - Concepts



Characteristics of HW based event device

- Millions of *flow queues*
- Events associated with a single flow queue can be scheduled on multiple CPUs for concurrent processing while maintaining the original event order
- Provides synchronization of the events without SW lock schemes
- Priority based scheduling to enable the *QoS*
- Event device may have 1 to N schedule groups
- Each core can be a member of any subset of schedule groups
  - Each core decides which schedule group(s) it accepts the events from
  - Schedule groups provide a means to execute different functions on different cores
- Flow queues grouped into schedule groups
- Core to schedule group membership can be changed at runtime to support scaling and reduce the latency of critical work by assigning more cores at runtime
- Event scheduler is implemented in HW to the save CPU cycles

libeventdev components



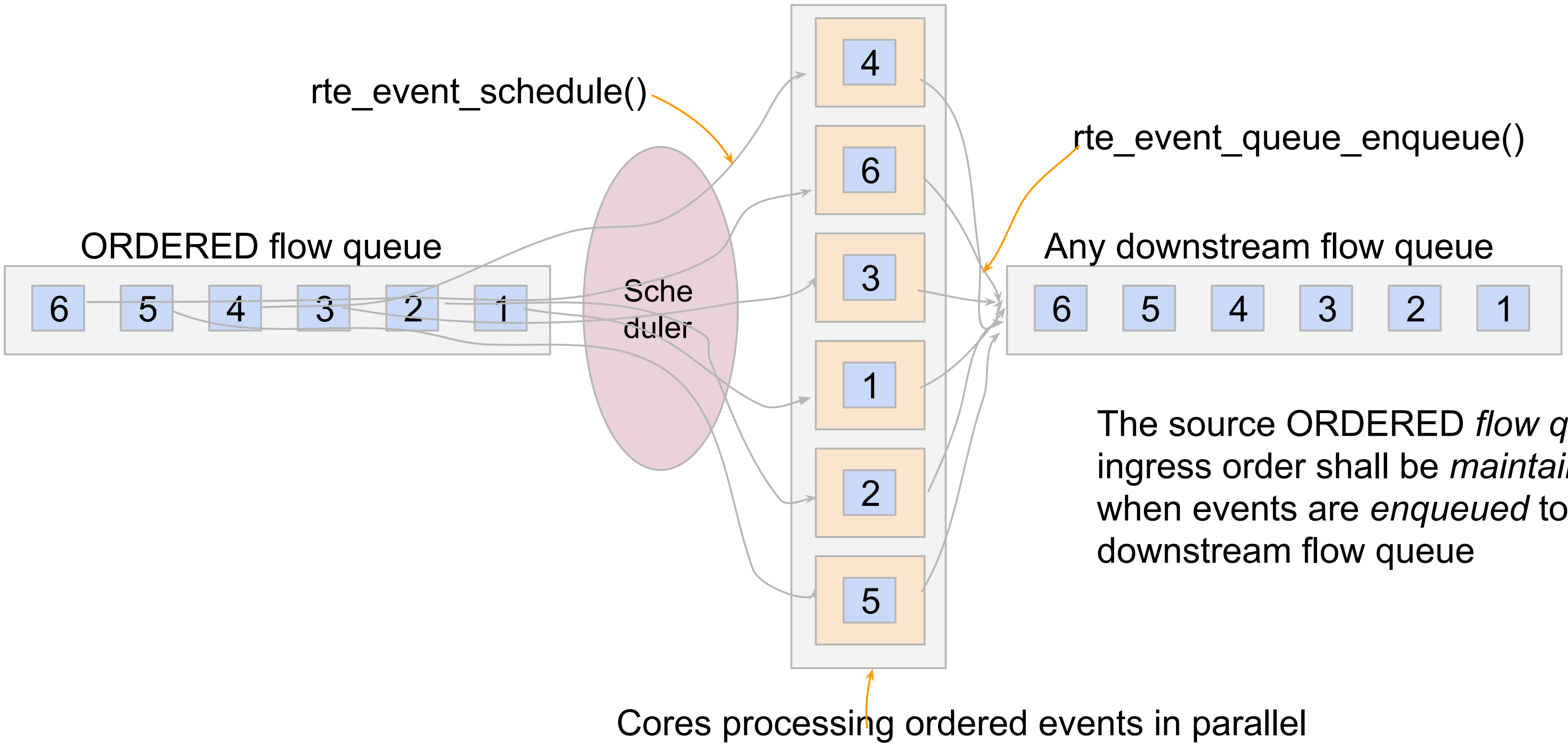
libeventdev - flow

- Event driver registers with libeventdev subsystem and subsystem provide a unique device id
- Application get the device capabilities with rte_eventdev_info_get(dev_id), like
  - The number of schedule groups
  - The number of flow queues in a schedule group
- Application configures the event device and each schedule groups in the event device, like
  - The number of schedule groups and the flow queues are required
  - Priority of each schedule group and list of l-cores associated with it
  - Connect schedule groups with other HW event producers in the system like ethdev and crypto etc
- In fastpath,
  - HW/SW enqueues the events to flow queues associated with schedule groups
  - Core gets the event through scheduler by invoking rte_event_scheduler() from lcore
  - Core process the event and enqueue to another downstream queue for further processing or send the event/packet to wire if it is the last stage of the processing
  - rte_event_scheduler() schedules the event based on
    - selection of the schedule group
      - The caller l-core membership in the schedule group
      - Schedule group priority relative to other schedule groups.
    - selection of the flow queue and the event inside the schedule group
      - Scheduler sync method associated with the flow queue(ATOMIC vs ORDERED/PARALLEL)

Schedule sync methods (How events are Synchronized)

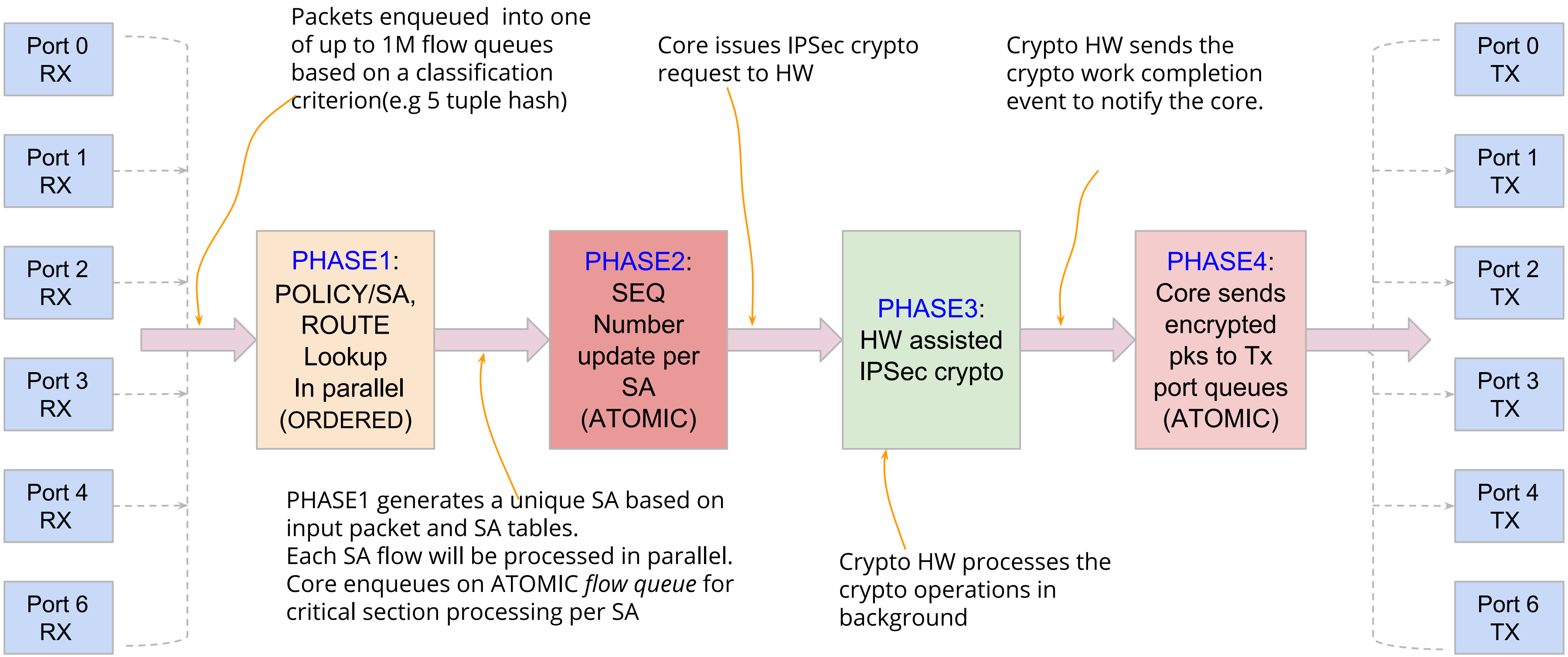
- PARALLEL
  - Events from a parallel flow queue can be scheduled to multiple cores for concurrent processing
  - Ingress order is *not* maintained
- ATOMIC
  - Events from an atomic flow queue can schedule only to a *single core* at a time
  - Enable critical section in packet processing like sequence number update etc
  - Ingress order is *maintained* as outstanding is always one at a time
- ORDERED
  - Events from the ordered flow queue can be scheduled to multiple cores for concurrent processing
  - Ingress order is *maintained*
  - Enable high *single flow* throughput

ORDERED flow queue for ingress ordering

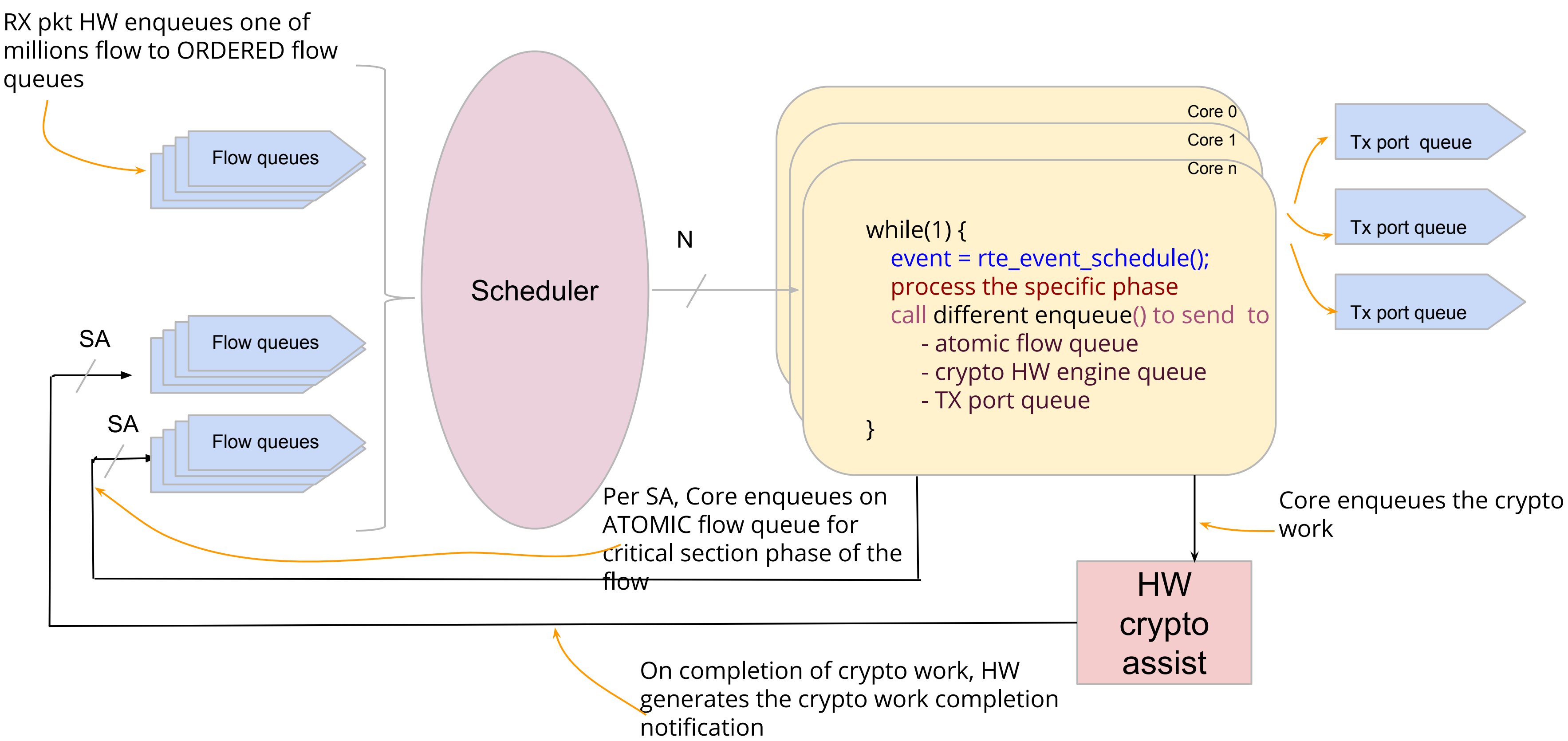


The source ORDERED *flow queue's* ingress order shall be *maintained* when events are *enqueued* to any downstream flow queue

Use case (Simple IPSec Outbound processing)



Simple IPSec Outbound processing - Cores View



Fast path APIs - Simple IPSec outbound example

```
#define APP_STATE_SEQ_UPDATE 0
on each lcore
{
	struct rte_event ev;
	uint32_t flow_queue_id_mask = rte_eventdev_flow_queue_id_mask(eventdev);

	while (1) {
		ret = rte_event_schedule(eventdev, &ev, true);
		 If (!ret)
			continue;

		/* packets from HW rx ports proceed parallely per flow(ORDERED)*/
		if (ev.event_type == RTE_EVENT_TYPE_ETHDEV) {
			sa = outbound_sa_lookup(ev.mbuf);
			 modify the packet per SA attributes
			 find the tx port and tx queue from routing table

			/* move to next phase (atomic seq number update per sa) */
			ev.flow_queue_id = sa & flow_queue_id_mask;
			ev.sched_sync = RTE_SCHED_SYNC_ATOMIC;
			ev.sub_event_id = APP_STATE_SEQ_UPDATE;
			rte_event_enqueue(evendev, ev);
		} else if (ev.event_type == RTE_EVENT_TYPE_LCORE && ev.sub_event_id == APP_STATE_SEQ_UPDATE) {
			sa = ev.flow_queue_id;
			/* do critical section work per sa */
			do_critical_section_work(sa);

			/* Issue the crypto request and generate the following on crypto work completion */
			ev.flow_queue_id = tx_port;
			ev.sub_event_id = tx_queue_id;
			ev.sched_sync = RTE_SCHED_SYNC_ATOMIC;
			rte_cryptodev_event_enqueue(cryptodev, ev.mbuf, eventdev, ev);
		}
		} else if((ev.event_type == RTE_EVENT_TYPE_CRYPTODEV)
			tx_port = ev.flow_queue_id;
			tx_queue_id = ev.sub_evend_id;
			send the packet to tx port/queue
		}
	}
}
```

Benefits of event driven programming model

- Enable high *single flow* throughput with ORDERED schedule sync method
- The processing stages are not bound to specific cores. It provides better load-balancing and scaling capabilities than traditional pipelining.
- Prioritize: Guarantee lcores work on the highest priority event available
- Support *asynchronous* operations which allow the cores to stay busy while hardware manages requests.
- Remove the static mappings between *core* to *port/rx queue*
- Scaling from 1 to N flows are easy as its not bound to specific cores

Backup slides

API Requirements

- APIs similar to existing ethernet and crypto API framework for
  - Device creation, device Identification and device configuration
- Enumerate libeventdev resources as numbers(0..N) to
  - Avoid ABI issues with handles
  - event device may have million *flow queues* so it's not practical to have handles for each flow queue and its associated name based lookup in multiprocess case
- Avoid *struct mbuf* changes
- APIs to
  - Enumerate eventdev driver capabilities and resources
  - Enqueue events from l-core
  - Schedule events
  - Synchronize events
  - Maintain ingress order of the events

API - Slow path

- APIs similar to existing ethernet and crypto API framework for
  - Device creation - Physical event devices are discovered during the PCI probe/enumeration of the EAL function which is executed at DPDK initialization, based on their PCI device identifier, each unique PCI BDF (bus/bridge, device, function)
  - Device Identification - A unique device index used to designate the event device in all functions exported by the eventdev API.
  - Device Capability discovery
    - rte_eventdev_info_get() - To get the global resources like number of schedule groups and number of flow queues per schedule group etc of the event device
  - Device configuration
    - rte_eventdev_configure() - configures the number of schedule groups and the number of flow queues on the schedule groups
    - rte_eventdev_sched_group_setup() - configures schedule group specific configuration like priority and the list of l-core has membership in the schedule group
  - Device state change - rte_eventdev_start()/stop()/close() like ethdev device

API - Fast path

- bool *rte_event_schedule*(uint8_t dev_id, struct rte_event *ev, bool wait);
    - Schedule an event to the caller l-core from a specific schedule group of event device designated by its dev_id
- bool *rte_event_schedule_from_group*(uint8_t dev_id, uint8_t group_id,struct rte_event *ev, wait)
    - Like rte_event_schedule(), but schedule group provided as argument
- void *rte_event_schedule_release*(uint8_t dev_id);
    - Release the current scheduler synchronization context associated with the scheduler dispatched event
- int *rte_event_schedule_group_[join/leave]*(uint8_t dev_id, uint8_t group_id);
    - Leave/Joins the caller l-core from/to a schedule group
- bool *rte_event_schedule_ctxt_update*(uint8_t dev_id, uint32_t flow_queue_id, uint8_t sched_sync, uint8_t sub_event_type, bool wait);
    - rte_event_schedule_ctxt_update() can be used to support run-to-completion model where the application requires the current *event* to stay on the same l-core as it moves through the series of processing stages, provided the event type is RTE_EVENT_TYPE_LCORE

Run-to-completion model support

- rte_event_schedule_ctxt_update() can be used to support run-to-completion model where the application requires the current *event* to stay on same l-core as it moves through the series of processing stages, provided the event type is RTE_EVENT_TYPE_LCORE(l-core to l-core communication)
- For example in the previous use case, the ATOMIC sequence number update per SA can be achieved like below

```
        /* move to next phase (atomic seq number update per sa) */
        ev.flow_queue_id = sa & flow_queue_id_mask;
        ev.sched_sync = RTE_SCHED_SYNC_ATOMIC;
        ev.sub_event_id = APP_STATE_SEQ_UPDATE;
        rte_event_enqueue(evendev, ev);
    } else if (ev.event_type == RTE_EVENT_TYPE_LCORE && ev.sub_event_id ==
APP_STATE_SEQ_UPDATE) {
        sa = ev.flow_queue_id;
        /* do critical section work per sa */
        do_critical_section_work(sa);
```

→

```
    /* move to next phase (atomic seq number update per sa) */

        rte_event_schedule_ctxt_update(eventdev,
sa & flow_queue_id_mask, RTE_SCHED_SYNC_ATOMIC,
APP_STATE_SEQ_UPDATE, true);

        /* do critical section work per sa */
        do_critical_section_work(sa);
```

- Scheduler context update is costly operation, by spliting it as two functions(rte_event_schedule_ctxt_update() and rte_event_schedule_ctxt_wait()) allows application to overlap the context switch latency with other profitable work

Future work

- Integrate the event device with ethernet, crypto and timer subsystems in DPDK
  - Ethdev/event device integration is possible by extending new 6WIND's ingress classification specification where a new ***action type*** can establish ethdev's *port* to eventdev's *schedule group* connection
  - Cryptodev needs some change at configuration stage to set *crypto work complete* event delivery mechanism
  - Spec out *timerdev* for PCI based timer event devices(timer event devices generates timer expiry event vs callback in the existing SW based timer scheme)
  - Event driven model operates on a single event at a time. Need to create a helper API to make it burst in nature for the *final enqueues* to different HW block like ethdev tx-queue