Armv8 WFE Mechanism and Usage in DPDK

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Agenda

- AArch64 WFE instruction
- New APIs
- Usage in DPDK
- Results

WFE instruction and supporting components

- WFE = Wait For Event
- When a CPU is in the wait state, it can be woken up by any event
- Events that can wake the CPU include:
  - SEV (send event),
  - loss of an exclusive monitor (in ArmV8).

WFE Instruction and Supporting Components

- A memory location is monitored
- Store to the location triggers core wake-up events
- Wake-up brings core out of low power state
- Spurious wake-ups are possible and must be handled

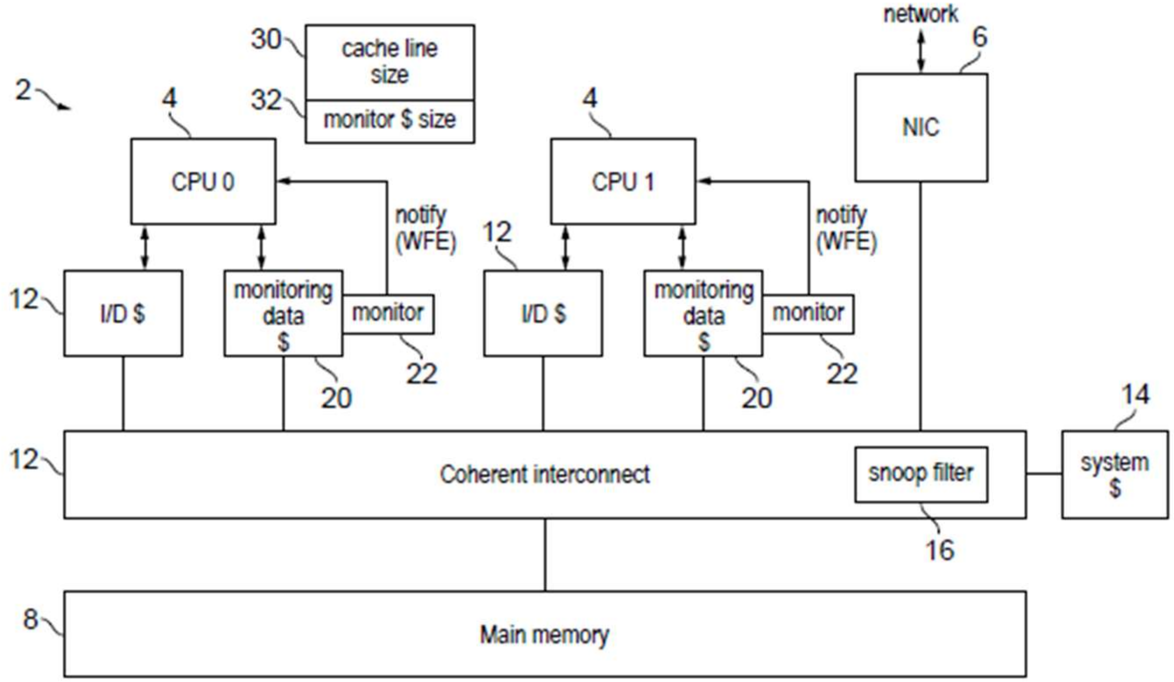


FIG. 1

WFE Working Generic Flow

1. Clear event registers
2. Activate monitoring of location
3. Wait (enter the low power state)
4. Wake up and continue processing

Abstract APIs

- Add the APIs of two memory model flavors
  - rte_wait_until_equal_relaxed_16/32/64
  - rte_wait_until_equal_acquire_16/32/64
- Abstract API implemented for all architectures
  - AArch64 implementation uses WFE and related instructions
  - Implement as continuous poll loop for other arches not implementing WFE

WFE Usage in Spinlock

- http://patches.dpdk.org/patch/59265/
- This implementation does not use the new API
  - To save the loading of zero and compare against it and the branch
- WFE may behave differently on different Arm cores, use recommended instruction sequence [1]

[1] https://developer.arm.com/docs/103489537/latest/why-do-different-cores-behave-differently-when-executing-a-wfe-instruction

WFE in Ticket Lock

- Wait for the current ticket number to equal my ticket
  - http://patches.dpdk.org/patch/59266/

```
--- a/lib/librte_eal/common/include/generic/rte_ticketlock.h
+++ b/lib/librte_eal/common/include/generic/rte_ticketlock.h
@@ -66,8 +66,7 @@  static inline void
 rte_ticketlock_lock(rte_ticketlock_t *tl)
 {
        uint16_t me = __atomic_fetch_add(&tl->s.next, 1, __ATOMIC_RELAXED);
-       while (__atomic_load_n(&tl->s.current, __ATOMIC_ACQUIRE) != me)
-               rte_pause();
+       rte_wait_until_equal_acquire_16(&tl->s.current, me);
 }
```

- This example shows how to employ the new API..

WFE in Ring Buffer

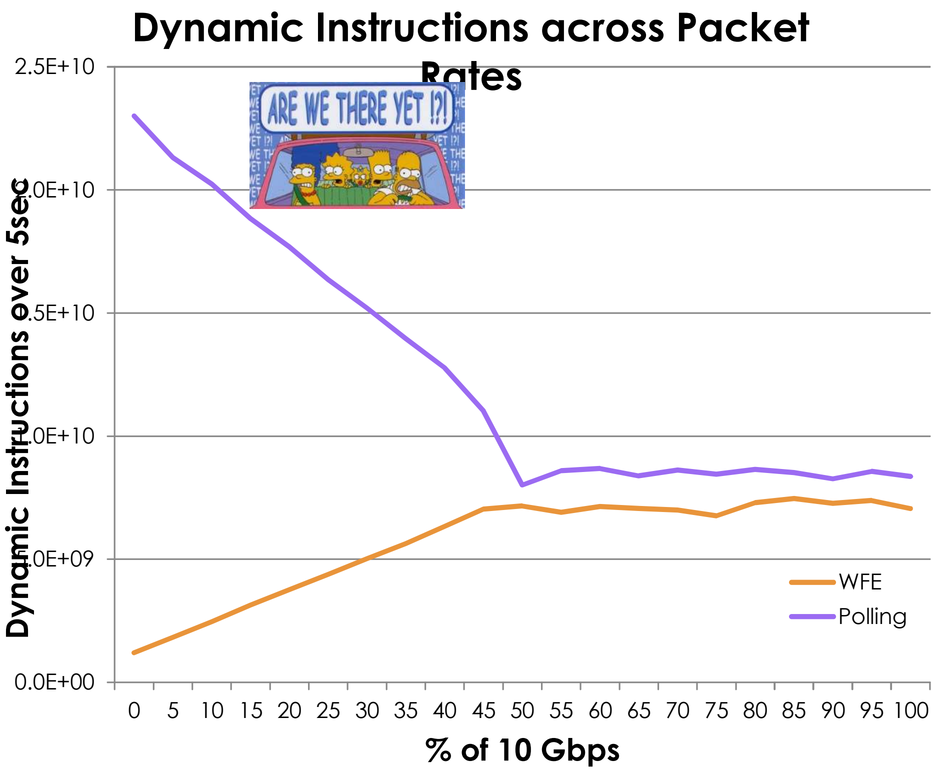
- Multiproducer (MP) and multiconsumer (MC) rings
  - Wait for ring tail to be updated by preceding P/C thread(s)
  - Tails have to be updated in the order of moving heads
- Update both generic and C11 ring implementations
- http://patches.dpdk.org/patch/59267/

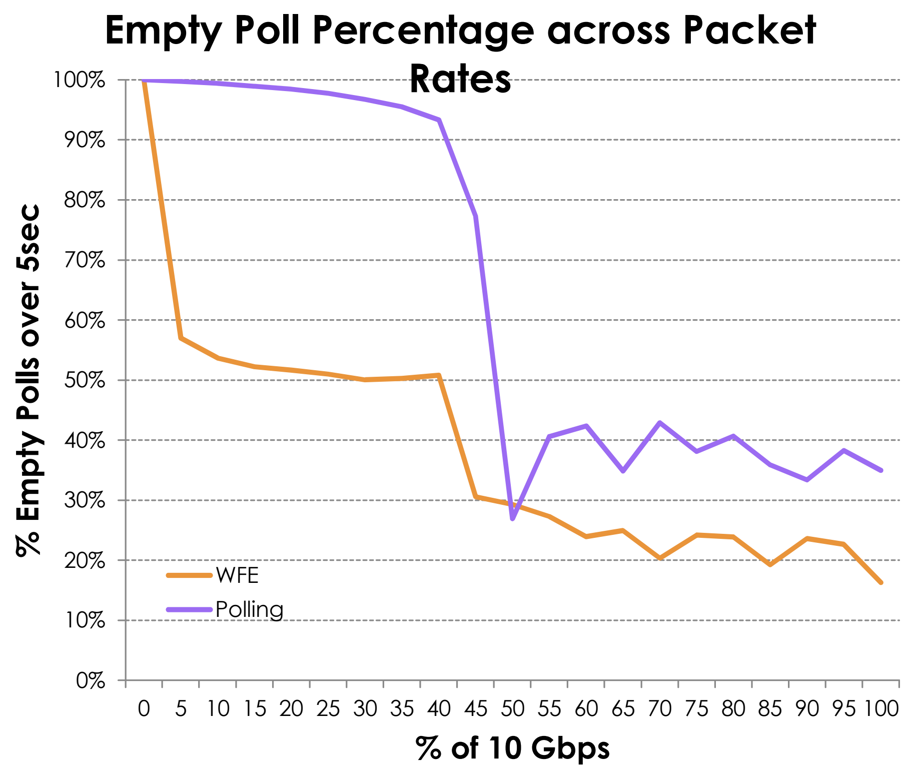
```
diff --git a/lib/librte_ring/rte_ring_generic.h b/lib/librte_ring/rte_ring_generic.h
index 953cdbb..6828527 100644
--- a/lib/librte_ring/rte_ring_generic.h
+++ b/lib/librte_ring/rte_ring_generic.h
@@ -23,8 +23,7 @@  update_tail(struct rte_ring_headtail *ht, uint32_t old_val, uint32_t new_val,
          * we need to wait for them to complete
          */
         if (!single)
-                while (unlikely(ht->tail != old_val))
-                        rte_pause();
+                rte_wait_until_equal_relaxed_32(&ht->tail, old_val);

         ht->tail = new_val;
 }
```

Other examples

- EVENT/OPDL
  - http://patches.dpdk.org/patch/59269/
- ThunderX NICVF
  - http://patches.dpdk.org/patch/59268/

Power efficiency potential of WFE with polling



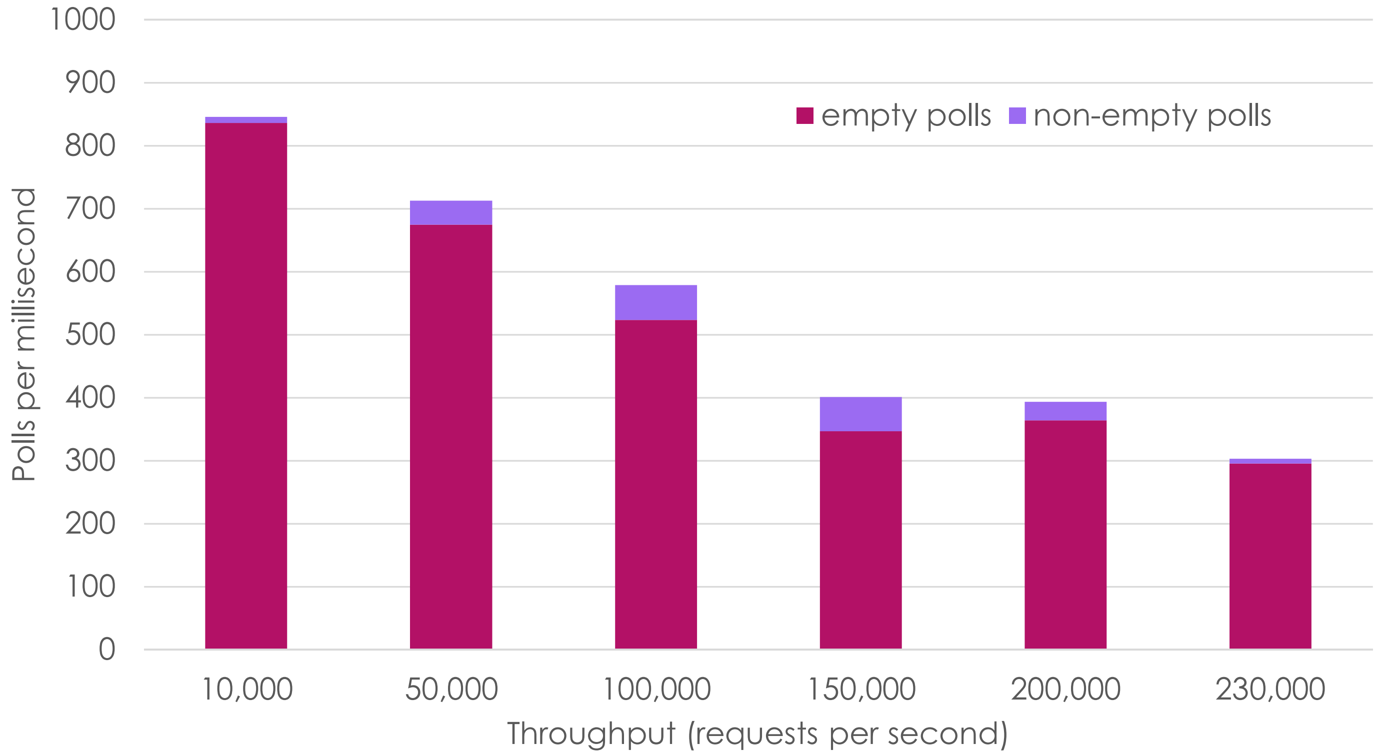


- **1 receive queue on NIC**

Mellanox ConnectX-5 driver (mlx5) in DPDK *modified to use WFE*

DPDK pktgen with 10 Gbps i’face to testpmd on ThunderX2 with mlx5

Polling: Wasteful of energy!



memcached using OFP + ODP-DPDK

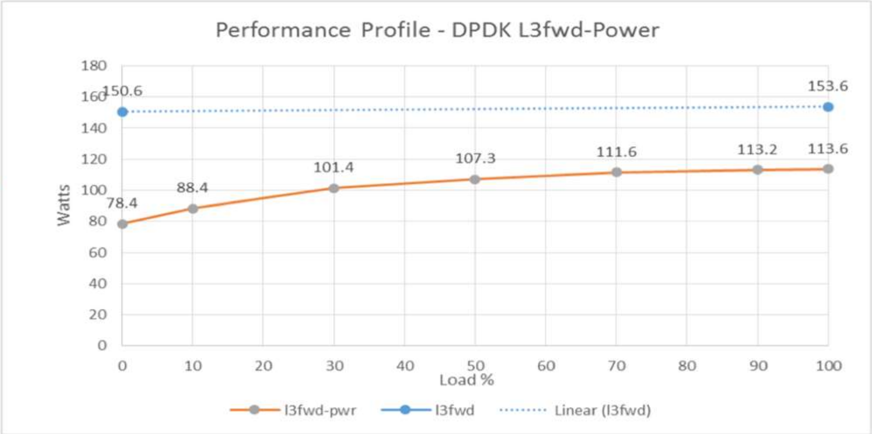
source:

Strategies for Improving Tail Latency for Poll-Based Networking, Steve Zekany (Arm intern 2017)

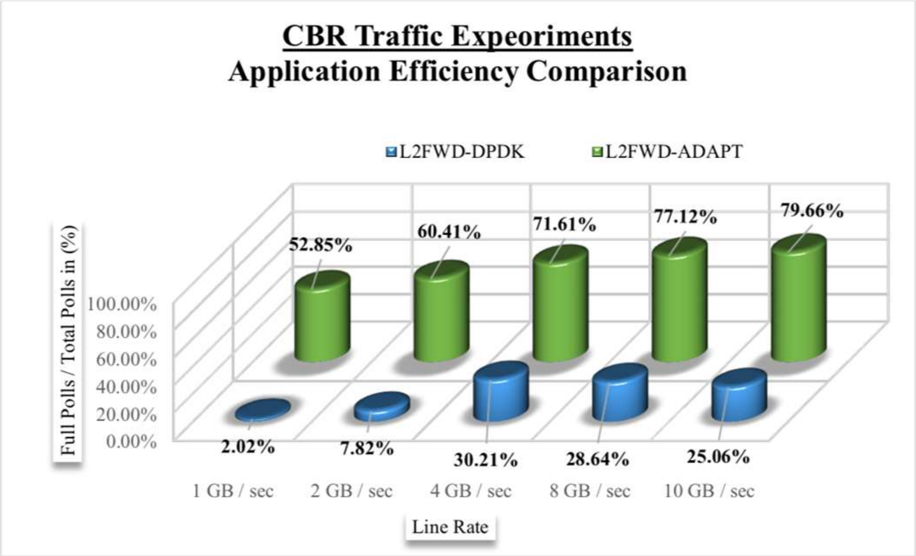
DPDK Power Optimization Research by Intel

Intel reported around 30% reduction in power consumption with L3fwd-power using on-demand CPU power state tuning.

“Based on a US EPA study, they assume that network equipment spends 25% of the time with high traffic (active state) and 75% of the time with low traffic (idle state)”

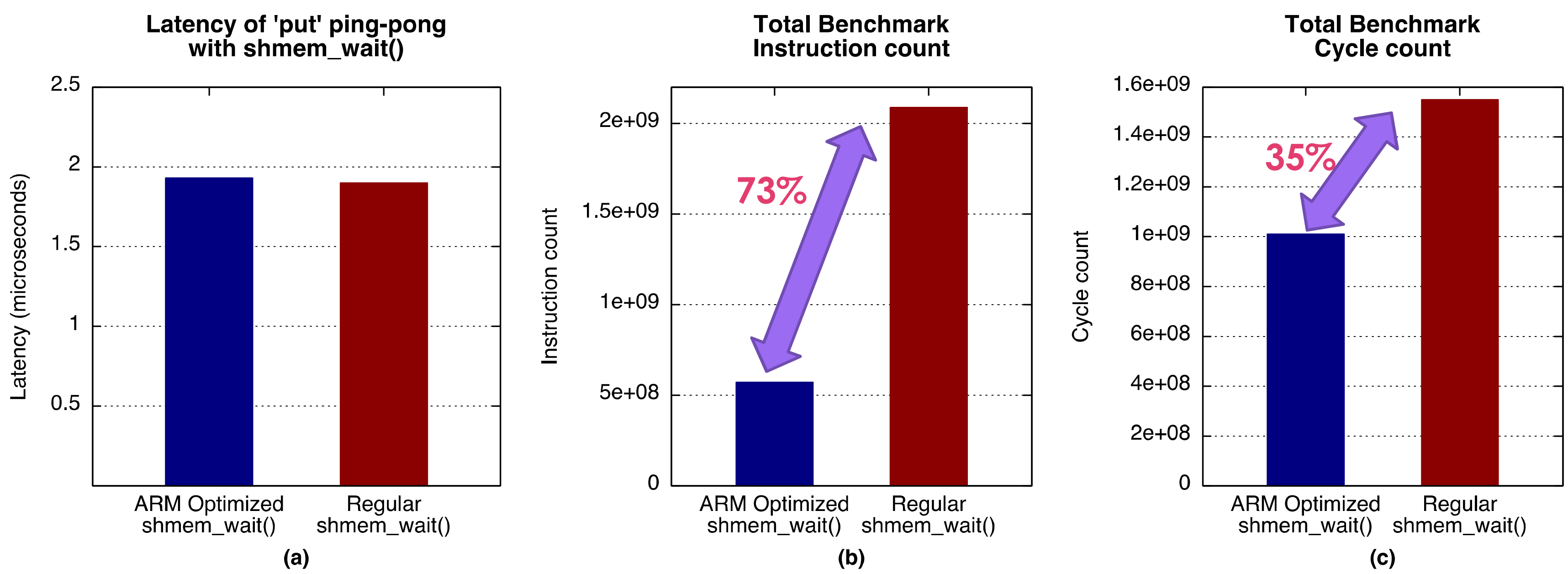


https://www.intel.com/content/dam/www/public/us/en/documents/white-papers/dpdk-power-optimization-advantech-white-paper.pdf



https://ulir.ul.ie/bitstream/handle/10344/6246/Hristo_Trifonov_Research_Report.pdf?sequence=2

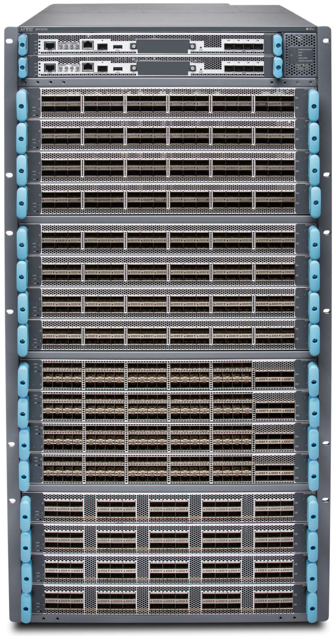
OpenSHMEM Wait with WFE (single address)



Enabling One-sided Communication Semantics on ARM, Shamis et al.,
IPDPSW 2017

More use cases

- Datacenter
  - ✓ Ethernet Poll Mode Driver (DPDK)
- HPC
  - MPI
  - ✓ OpenSHMEM
  - RDMA user level poll mode
- Thread communication over shared memory
- Direct block device I/O (Linux io_uring)
- POSIX asynchronous I/O
- Generic I/O multiplexing facility (epoll in hardware)



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Thanks