OpenPOWER™

A software developer's introduction to OpenCAPI

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OpenCAPI

Open Coherent Accelerator Processor Interface

Coherent
High bandwidth
Low latency
Designed for FPGAs
Open standard
Available today on POWER9

skiboot

github.com/open-power/skiboot
(hw/npu2-opencapi.c)

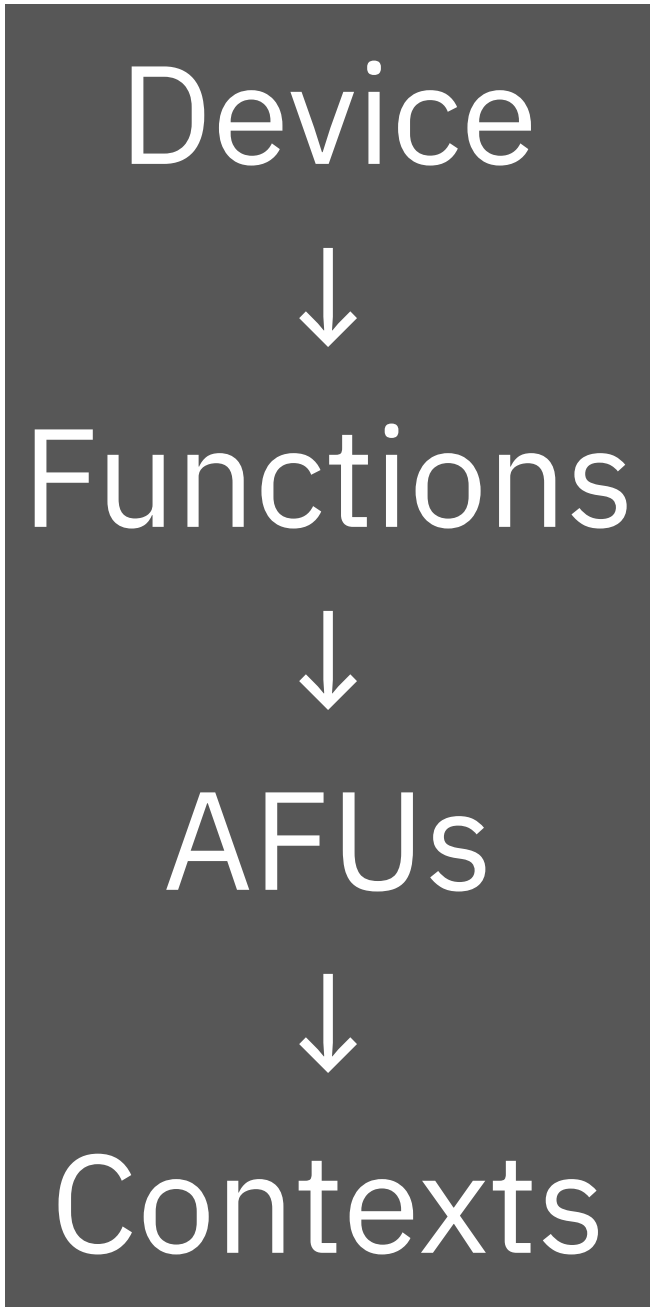
```
[   66.300124422,5] OPAL v6.1-115-g23d5532076ba-debug starting...
...
[   84.378110109,6] NPU: Chip 8 Found NPU2#1 (6 links) at
                    /xscom@623fc00000000/npu@5011000
...
[   85.211655161,7] PLAT: Chip 8 GPU#0 slot present
[   85.211689090,7] PLAT: Chip 8 GPU#0 is OpenCAPI
...
[   88.454427431,6] OCAPI[8:3]: link trained in 108 ms
...
[   88.460301163,7] PHB#0008:00:00.0 Link up at x8 width
[   88.460302626,7] PHB#0008:00:00.0 Scanning (upstream+downsteam)...
[   88.460327984,7] PHB#0008:00:00.0 Found VID:1014 DEV:062b TYP:1 MF+ BR- EX-
[   88.460341774,7] PHB#0008:00:00.1 Found VID:1014 DEV:062b TYP:1 MF+ BR- EX-
```

OpenCAPI looks like PCI

```
ubuntu@wcapilp4:/dev/ocxl$ sudo lspci -v

0006:00:00.0 Processing accelerators: IBM Device 062b
        Subsystem: IBM Device 060f
        Flags: fast devsel
        Memory at 600e804000000 (64-bit, non-prefetchable) [size=16]
        Memory at 600e804010000 (64-bit, non-prefetchable) [size=16]
        Memory at 600e804020000 (64-bit, non-prefetchable) [size=16]
        Expansion ROM at <ignored> [disabled]
        Capabilities: [40] Vital Product Data
        Kernel driver in use: ocxl
        Kernel modules: ocxl

0006:00:00.1 Processing accelerators: IBM Device 062b
        Subsystem: IBM Device 060f
        Flags: fast devsel
        Memory at 600e800000000 (64-bit, non-prefetchable) [size=64M]
        Memory at 600e804030000 (64-bit, non-prefetchable) [size=16]
        Memory at 600e804040000 (64-bit, non-prefetchable) [size=16]
        Expansion ROM at <ignored> [disabled]
        Kernel driver in use: ocxl
        Kernel modules: ocxl
```


Device
↓
Functions
↓
AFUs
↓
Contexts

AFU

Attached Functional Unit

Contexts → PASIDs

Process Address Space ID


MMIO

ocxl

drivers/misc/ocxl/

```
ubuntu@wcapilp4:/dev/ocxl$ ls -l
total 0
crw------- 1 root root 242, 0 Jan 28  2018 IBM,MEMCPY3.0006:00:00.1.0
```

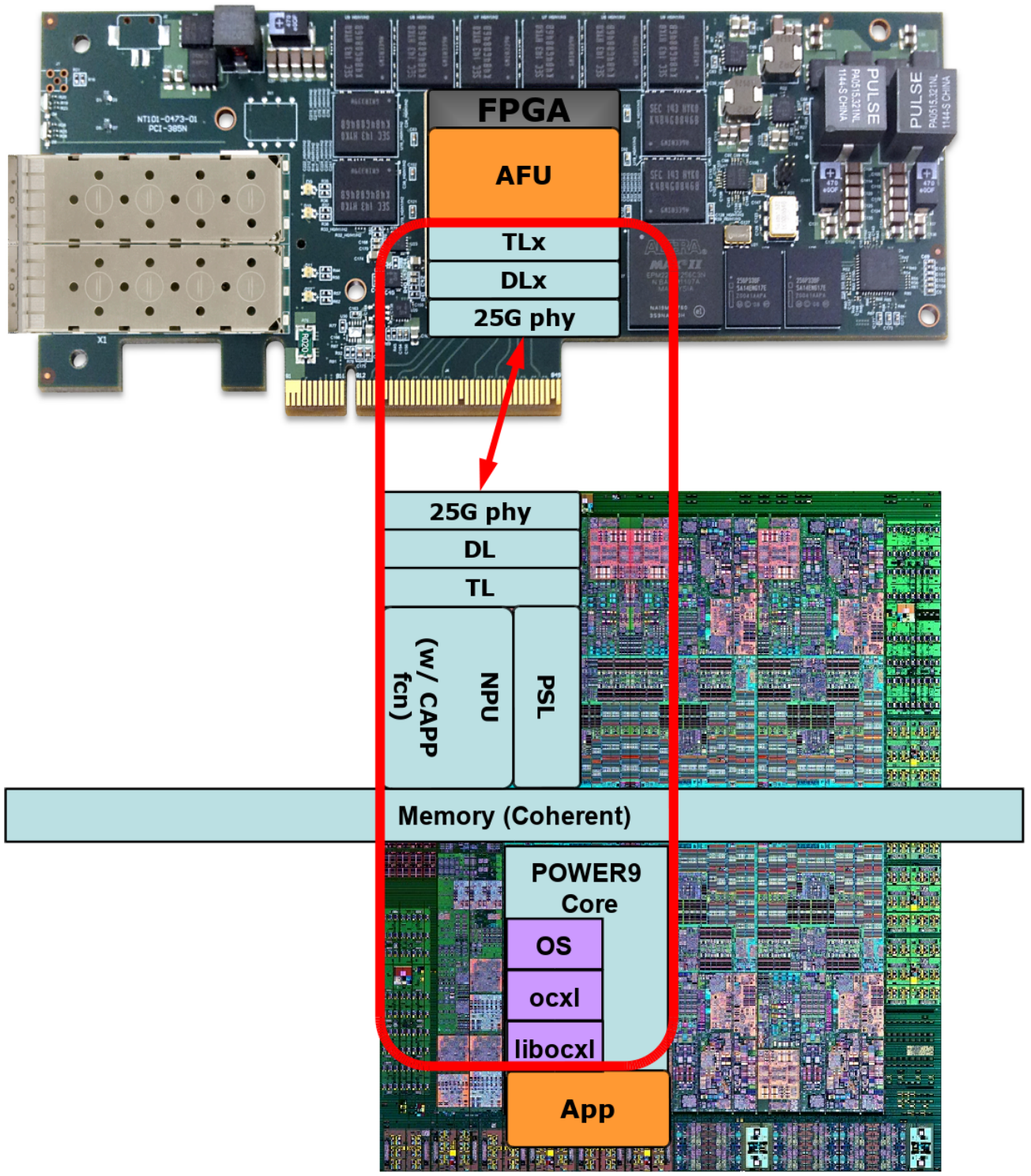
libocxl

github.com/opencapi/libocxl

```
$ sudo {apt,yum} install libocxl-dev
```

OCSE

OpenCAPI Simulation Engine


FPGA
AFU
TLx
DLx
25G phy
25G phy
DL
TL
NPU (w/ CAPP fcn)
PSL
Memory (Coherent)
POWER9 Core
OS
ocxl
libocxl
App
POWER9 Processor

memcpy

libocxl/samples/memcpy/

```
#include "libocxl.h"
#define AFU_NAME "IBM,MEMCPY3"
#define MEMCPY_SIZE 2048

int main(int argc, char *argv[])
{
    ocxl_afu_h afu;

    ocxl_enable_messages(OCXL_ERRORS | OCXL_TRACING);
    ocxl_afu_open(AFU_NAME, &afu);
    global_setup(afu);

    char *src = aligned_alloc(64, MEMCPY_SIZE);
    char *dst = aligned_alloc(64, MEMCPY_SIZE);
    fill_buffer(src, MEMCPY_SIZE);
    memset(dst, '0', MEMCPY_SIZE);
    afu_memcpy(afu, src, dst, MEMCPY_SIZE, 0, 10); /* Use polling, 10ms timeout */

    if (memcmp(dst, src, MEMCPY_SIZE))
        LOG_ERR("Memory contents do not match\n")

    ocxl_afu_close(afu);
}
```

```
struct memcpy_work_element {
    volatile uint8_t cmd; /* valid, wrap, cmd */
    volatile uint8_t status;
    union {
        uint16_t length;
        uint16_t tid;
    };
    uint8_t cmd_extra;
    uint8_t reserved[3];
    uint64_t atomic_op;
    uint64_t src;  /* also irq EA or atomic_op2 */
    uint64_t dst;
} __packed;

struct memcpy_weq {
    struct memcpy_work_element *queue;
    struct memcpy_work_element *next;
    struct memcpy_work_element *last;
    int wrap;
    int count;
};
```

```
static bool afu_memcpy(ocxl_afu_h afu, const char *src, char *dst,
                       size_t size, int completion, int timeout)
{
        uint64_t wed;
        struct memcpy_weq weq;

        memcpy3_init_weq(&weq, QUEUE_SIZE);

        // Point the work element descriptor (wed) at the work queue
        wed = MEMCPY_WED(weq.queue, QUEUE_SIZE / CACHELINESIZE);

        // Setup a work element in the queue
        struct memcpy_work_element memcpy_we;
        memset(&memcpy_we, 0, sizeof(memcpy_we));
        memcpy_we.cmd = MEMCPY_WE_CMD(0, MEMCPY_WE_CMD_COPY);
        memcpy_we.length = htole16((uint16_t) size);
        memcpy_we.src = htole64((uintptr_t) src);
        memcpy_we.dst = htole64((uintptr_t) dst);
```

```
ocxl_afu_attach(afu, OCXL_ATTACH_FLAGS_NONE);

// Map the per-PASID MMIO space
ocxl_mmio_h pp_mmio;
ocxl_mmio_map(afu, OCXL_PER_PASID_MMIO, &pp_mmio);

// Allocate an IRQ to report errors
ocxl_irq_h err_irq;
ocxl_irq_alloc(afu, NULL, &err_irq);

// Let the AFU know the handle to trigger for errors
uint64_t err_irq_handle = ocxl_irq_get_handle(afu, err_irq);

ocxl_mmio_write64(pp_mmio, MEMCPY_AFU_PP_IRQ,
                  OCXL_MMIO_LITTLE_ENDIAN, err_irq_handle);
```

```
// Write the address of the work element descriptor to the AFU
ocxl_mmio_write64(pp_mmio, MEMCPY_AFU_PP_WED,
                  OCXL_MMIO_LITTLE_ENDIAN, wed);

// setup the work queue
struct memcpy_work_element *memcpy_element =
                memcpy3_add_we(&weq, &memcpy_we);
struct memcpy_work_element *stop_element = NULL;
struct memcpy_work_element stop_we;
memset(&stop_we, 0, sizeof(stop_we));
stop_we.cmd = MEMCPY_WE_CMD(1, MEMCPY_WE_CMD_STOP);

stop_element = memcpy3_add_we(&weq, &stop_we);
```

```
        // memory barrier to ensure the descriptor is written to
        // memory before we ask the AFU to use it
        __sync_synchronize();

        // Initiate the memcpy
        memcpy_element->cmd |= MEMCPY_WE_CMD_VALID;

        // Wait for the AFU to be done
        wait_for_status(timeout, afu, memcpy_element, err_irq_handle);
        wait_for_status(timeout, afu, stop_element, err_irq_handle);
}
```

```
ubuntu@wcapilp4:~/libocxl/sampleobj$ sudo ./memcpy
AFU config = 0x0
traces reset and rearmed
WED=0x745140490fff  src=0xa85f14208c0  dst=0xa85f1421140 size=2048
Memory contents match
```

opencapi.org
opencapi.github.io

Thank you

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