Successfully Deploying Persistent Memory and Acceleration via Compute Express Link!

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Beyond NVDIMM: Future Interfaces for Persistent Memory

Stephen Bates, Microsemi
Persistent Memory (PM)

- Low Latency
- Memory Semantics
- Storage Features
What is Needed?

- Media and Form-Factors
- Protocols and Interconnect
- OS Support
- Libraries and Toolchain

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Coming Soon to a Cinema Near You!

**GEN Z**
A New Fabric

- featuring Optional coherency
- NVMe support
- Scale

Coming in 2020

**CCIX**
The ARMpire Strikes Back

- featuring Off the CPU bus
- Accelerator support
- Cache coherency
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Now Showing in Select Cinemas

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Broad Industry support for CXL

CXL consortium - Currently 75 companies and growing

www.computeexpresslink.org
• All the CPU vendors I care about are now CXL members.
• Same cannot be said for OpenCAPI, CCIX or Genz
• Remember, coherent buses MUST come directly out of the CPU!
CXL Protocols

The CXL transaction layer is comprised of 3 dynamically multiplexed sub-protocols on a single link:

- **CXL.io** - Discovery, configuration, register access, interrupts, etc.
- **CXL.cache** - Device access to processor memory
- **CXL.memory** - Processor access to device attached memory

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**CXL - Dynamically Multiplexed IO, Cache and Memory**

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All Information Confidential (CXL Consortium)
Let’s break that down. Three protocols on one physical layer:

- **CXL.io**: This is PCIe Gen 5.0. All PCIe services will just work!
  - DMA
  - Interrupts (MSI/MSIX)
  - SR-IOV, ACS, ATS etc. for virtualization
  - NVM Express!!!??? – We will come back to this

- **CXL.mem**: This is the protocol by which the host CPU accesses (persistent) memory on the CXL device.

- **CXL.cache**: The is the protocol by which the CXL device accesses host memory (useful for accelerators, not covered here today).
Representative CXL usages

Caching Devices / Accelerators
- Usages:
  - PGAS NIC
  - NIC atomics
  - Protocols:
    - CXL.io
    - CXL.cache

Accelerators with Memory
- Usages:
  - GPU
  - Dense Computation
  - Protocols:
    - CXL.io
    - CXL.cache
    - CXL.memory

Memory Buffers
- Usages:
  - Memory BW expansion
  - Memory capacity expansion
  - Persistent Memory
- Protocols:
  - CXL.io
  - CXL.mem

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Let’s break that down. Consider the right-most model:

- Essentially a NVDIMM but no longer constrained by the physical and electrical requirements of DDR and DIMMs.
- Since the form-factors are PCIe we have more options around the shape, power and heat of these solutions.
- The CXL.io allows for discovery, configuration and management (we can write a PCIe driver for these devices).
- We can put a DMA engine on the Memory Buffer and program that via PCIe to do data movement for us.
- No longer consuming DIMM slots or channels. Save all that capacity and bandwidth for standard DRAM.
# DDR NVDIMM vs CXL NVDIMM

<table>
<thead>
<tr>
<th>Attribute</th>
<th>DDR</th>
<th>CXL</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form-factor</td>
<td>DIMM</td>
<td>Many</td>
<td>CXL has many form-factor options</td>
</tr>
<tr>
<td>DMA</td>
<td>No</td>
<td>Yes</td>
<td>CXL allows placement on DMA engine on device. Can be programmed via PCIe driver.</td>
</tr>
<tr>
<td>HW Virtualization</td>
<td>No</td>
<td>SR-IOV</td>
<td>NVDIMM can be virtualized via software which impacts performance.</td>
</tr>
<tr>
<td>Management</td>
<td>SMBus and MMIO</td>
<td>SMBus and MMIO and CXL.io</td>
<td>If we adopt NVMe for CXL devices we can use NVMe Management Interface (NVMe-MI).</td>
</tr>
<tr>
<td>Latency</td>
<td>Very Low</td>
<td>Low</td>
<td>Until we get hardware it is hard to get comparative numbers for NVDIMM vs CXL.mem to the same memory types (e.g. 3DXP).</td>
</tr>
<tr>
<td>Throughput</td>
<td>19GB/s</td>
<td>64GB/s</td>
<td>NVDIMM is 64 bits @ 2400MT/s/channel. CXL is (upto) 16 lanes of PCIe Gen 5 in each direction.</td>
</tr>
</tbody>
</table>
(Persistent) Memory discovery will be done via ACPI. This can include Heterogenous Memory Attribute Tables (HMAT) to describe properties of the memory.

The discovered memory will be added to the physical memory pool.

We can control how and who this memory is used by to some extent by the numactl framework.

*If* the CXL device has a DMA engine and accelerator(s) these can be programmed via a PCIe driver (perhaps NVM Express).
CXL-based NVDIMM:

- Use all the DIMM slots for DRAM, not NVDIMM.
- NVM can be managed by controller chip if needed.
- A lot more flexibility on form-factor, power etc than DDR based NVDIMM.
- A DMA engine on CXL device could assist with data movement.
- Can also be used just to expand volatile memory capacity.
NoLoad® NVMe-based Computational Storage Processor

Best-In-Class Storage and Analytic Acceleration delivered via an NVMe-based Computational Storage Processor.
NVM Express for CXL

CXL features for 2.0:

• Improved throughput and latency (PCIe Gen6).
• Switching via enhanced PCIe switches
• Memory pooling (allowing multiple hosts to connect to a pool of (persistent) memory.)
Conclusions

• CXL may finally be bringing some clarity to the “Star Wars” of open, coherent buses.
• Minimal software changes needed to deploy (persistent) memory on CXL.
• Adding acceleration and remote PM both possible.
• We all get a pony!