Intel® Xeon Phi™ “Knights Landing” (KNL) System Software
Clark Snyder, Peter Hill, John Sygulla
Motivation

- The Intel® Xeon Phi™ “Knights Landing” (KNL) has 20 different configurations
  - 5 NUMA modes X 4 memory modes = 20 configurations
- How do I, as a user or system administrator, manage these options on my Cray® XC™ System?
Agenda

- As a user, how do I…
  - Choose the best configuration?
  - Configure the KNLs?
  - Figure out how the KNLs are configured?
  - Use zonesort and what is it?
- As a system administrator, how do I…
  - Configure the KNLs?
  - Figure out how the KNLs are configured?
- Are there costs to reconfiguration?
- Summary
- Q&A
KNL Architecture Overview

- **Processing elements**
  - Each tile has 2 cores
  - Each core has 4 threads

- **MCDRAM configuration**
  - Allocates MCDRAM between cache and addressable (flat) memory (4 options)

- **NUMA**
  - Splits tiles, DDR, and flat MCDRAM 1, 2, or 4 ways (5 options)
  - Addressable MCDRAM is always in separate NUMA node(s) from DDR and CPUs
KNL Architecture Overview – a2a, hemi, quad

- NUMA: all-to-all (a2a), hemisphere (hemi), quadrant (quad)
  - Change internal data flows
  - Only externally visible difference is performance

- MCDRAM:
  - If 100% cache, NUMA node 1 disappears

Note: Relative weights on lines indicate kernel allocation preference where lower numbers are preferred
💕 NUAL: sub-NUMA cluster 2 (snc2)
- Divides DDR and tiles into 2 NUMA nodes
- Divides flat MCDRAM into 2 NUMA nodes

 Zika MCDRAM:
- If 100% cache, NUMA nodes 2 & 3 disappear

Note: Relative weights on lines indicate kernel allocation preference where lower numbers are preferred
KNL Architecture Overview – snc4

- **NUMA: sub-NUMA cluster 4 (snc4)**
  - Divides DDR and tiles into 4 NUMA nodes
  - Divides flat MCDRAM into 4 NUMA nodes

- **MCDRAM:**
  - If 100% cache, NUMA nodes 4-7 disappear

Note: Relative weights on lines indicate kernel allocation preference where lower numbers are preferred
Which configuration should I use?

- **Job placement is harder in SNC modes**
  - Flat MCDRAM compounds the difficulty
  - SNC4 on 7250 results in unequal tile/core counts per NUMA node

- **Easiest configuration to use is quad/cache**
  - It performs well for most codes with the least fussing
  - No issue with uneven numbers of cores per NUMA node
  - No need to force memory allocations into flat MCDRAM

For more performance information, refer to the CUG tutorial “Getting the Most Out of Knights Landing” by John Levesque

<table>
<thead>
<tr>
<th>KNL SKU</th>
<th>Total Tiles</th>
<th>NN 0 Tiles</th>
<th>NN 1 Tiles</th>
<th>NN 2 Tiles</th>
<th>NN 3 Tiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>7210</td>
<td>32</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>7230</td>
<td>32</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>7250</td>
<td>34</td>
<td><strong>9</strong></td>
<td><strong>9</strong></td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

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How can a user configure a KNL?

- Use the workload manager (WLM) to request a configuration for your job
  - The WLM will match your request to pre-configured nodes; and/or
  - Reconfigure nodes to meet your request

- Examples:

  | Moab   | $ msub -l os=CLE_quad_flat run_script |
  | PBS    | $ qsub -l aoe=quad_0 run_script       |
  | Slurm  | $ sbatch -C quad,flat run_script      |

- Upcoming CLE6.0UP04 feature: report node reconfiguration state as “rebootq”, rather than “down”, in xtnodestat, xtprocadmin and apstat
How is the KNL currently configured?

- ALPS ‘apstat –M’ (from login node)

```
$ apstat -M
NID  Memory(MB)  HBM(MB)  Cache(MB)  NumaCfg
 24    114688   16384      0    quad
 25    106496   16384     8192  quad
```

- Slurm ‘sinfo’ (from login node)

```
$ sinfo -o "%N %f" NODELIST AVAIL_FEATURES nid00[008-047,052-063,072-115,120-127,140-191] flat,split,equal,cache,a2a,snc2,snc4,hemi,quad
```

- cnselect (from login node)

```
$ cnselect hmbcachepct.eq.100.and.numa_cfg.eq.quad
24-27,56-59,68-75,92-94,144-147,160-179
```

- hwloc: lstopo (from compute node)

```
$ aprun -qL 58 lstopo-no-graphics
Machine (94GB total) + NUMANode L#0 (P#0 94GB) + Package L#0 + L3(MemorySideCache) L#0 (16GB)
```
What is zonesort and how do I use it?

- **Issue**
  - MCDRAM cache is a physically addressed, direct-mapped
    - (Physical address) modulo (cache size) = (cache address)
    - (RAM size) module (cache size) = (number of conflicting addresses)
  - As memory is allocated and freed, the actual physical memory that is free changes as does the order in which this memory is placed on the free list
  - If two hot memory addresses vie for the same cache line:
    - Cache evictions go up and performance goes down
    - Performance may vary significantly from run to run

- **How zonesort helps**
  - Sorts memory on the free list by physical address
    - Improves run-time consistency by putting free memory in a consistent order
  - Invoked automatically by ALPS and Slurm
  - Supported by SchedMD in Slurm 17.02 release
  - Upcoming CLE 6.0UP04 ALPS feature to periodically invoke zonesort during an application run
How can an administrator configure a KNL?

- `capmc set_mcdram_cfg | set_numa_cfg`
  - But, the configuration won’t take effect until the next reboot
  - The `capmc node_reinit` command will bounce and boot nodes

```bash
crayadm@smw:~> capmc set_numa_cfg -n 59 -m quad -p
crayadm@smw:~> capmc set_mcdram_cfg -n 59 -m flat -p
crayadm@smw:~> capmc node_reinit -n 59
{
  "e":0,
  "err_msg":"Success"
}
```
How will the KNL be configured next?

- `capmc get_mcdram_cfg | get_numa_cfg (SMW | login)`
  - But remember `capmc` shows settings to use during next boot, which *may or may not* match the current configuration.

```
crayadm@smw:~> capmc get_mcdram_cfg -pn 24,128
NID         | MCDRAM Mode | DRAM Size | MCDRAM Size
--------------|-------------|-----------|--------------
   24         | cache/100   | 96GB      | 16384MB      
   128        | flat/0      | 96GB      | 16384MB      
Success

 crayadm@smw:~> capmc get_numa_cfg -pn 24,128
NID         | NUMA Mode 
--------------|-----------
   24         | quad      
   128        | a2a       
Success
```
How is the KNL currently configured?

- xthwinv

```bash
$ crayadm@smw:~> xthwinv -x c0-0c0s14
...
  <mcdram_memory size="16384" units="MB">
    <count>8</count>
    <max_speed>7.2</max_speed>
    <cfg_total>16384</cfg_total>
    <cfg_cache>16384</cfg_cache>
    <cfg_flat>0</cfg_flat>
    <mcdram_cfg>cache</mcdram_cfg>
  </mcdram_memory>
  <numa_cfg>quad</numa_cfg>
...
How was the KNL configured?

- Console log on the SMW (/var/opt/cray/log/p0-current/console-<date>)
- BIOS messages show configuration information at each boot

```
2016-04-08T07:03:07.486640-05:00 c0-c0s14n0  BUS_STATUS: DDR4 memSpeed = 0x0960
2016-04-08T07:03:07.486659-05:00 c0-c0s14n0  MCDRAM Active count = 0xFF
2016-04-08T07:03:07.486676-05:00 c0-c0s14n0  MCDRAM speed = 0x48
2016-04-08T07:03:07.486694-05:00 c0-c0s14n0  MCDRAM totalMem = 0x00000100
2016-04-08T07:03:07.486712-05:00 c0-c0s14n0  MCDRAM totalCache = 0x00000100
2016-04-08T07:03:07.486731-05:00 c0-c0s14n0  MCDRAM totalFlat = 0x00000000
2016-04-08T07:03:07.486748-05:00 c0-c0s14n0  MCDRAM memoryModel = 0x04
2016-04-08T07:03:07.486770-05:00 c0-c0s14n0  MCDRAM memoryMode = 0x00
2016-04-08T07:03:07.486781-05:00 c0-c0s14n0  MCDRAM totalClusters = 0x04
2016-04-08T07:03:07.486793-05:00 c0-c0s14n0  MCDRAM cacheRatio = 0x04
```
**How was the KNL configured? (BIOS decoder)**

<table>
<thead>
<tr>
<th>MCDRAM memoryModel</th>
<th>capmc NUMA config</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>a2a</td>
</tr>
<tr>
<td>0x01</td>
<td>snc2</td>
</tr>
<tr>
<td>0x02</td>
<td>snc4</td>
</tr>
<tr>
<td>0x03</td>
<td>hemi</td>
</tr>
<tr>
<td>0x04</td>
<td>quad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MCDRAM memoryMode</th>
<th>MCDRAM cacheRatio</th>
<th>capmc MCDRAM config</th>
<th>cache % of MCDRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00</td>
<td>0x04</td>
<td>cache/100</td>
<td>100%</td>
</tr>
<tr>
<td>0x01</td>
<td>0x00</td>
<td>flat/0</td>
<td>0%</td>
</tr>
<tr>
<td>0x02</td>
<td>0x01</td>
<td>split/25</td>
<td>25%</td>
</tr>
<tr>
<td>0x02</td>
<td>0x02</td>
<td>equal/50</td>
<td>50%</td>
</tr>
</tbody>
</table>
How was the KNL configured?

- **SMW commands log** (/var/opt/cray/log/commands/log.<date>)
  - Tracks the subcommands issued, e.g. xtbounce, xtcli boot
- **xtremoted log** (/var/opt/cray/log/xtremoted-<date>)
  - Captures the capmc operations

```plaintext
<157>1 2017-04-18T08:28:58.633589-05:00 smw xtremoted 48520 - [hss_xtremoted@34] auth_cb: Remote IP (172.30.49.161) URI(/capmc/set_mcdramCfg) request is authorized
```
Are there downsides to reconfiguration?

● More choices…
  ● For users and administrators

● Reconfiguration requires rebooting the compute node(s), which…
  ● Is not 100% reliable
  ● Takes time

See also the CUG presentation “CLE 6 Boot Performance and Reliability”, by Joel Landsteiner, which is part of the tutorial “Migrating, Managing, and Booting Cray XC and CMC/eLogin…”
### Boot and reconfiguration times at scale

**Argonne Theta • 20-cabinet Cray XC40 system • 3,624 Xeon Phi 7230 compute nodes • CLE 6.0/8.0.UP03 • 27 March 2017**

#### System Boot, time in seconds [1]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tr>
<td>44</td>
<td>738</td>
<td>408</td>
<td>52</td>
<td>346</td>
<td>126</td>
<td>729</td>
<td>65</td>
<td>2508</td>
</tr>
</tbody>
</table>

41'48"

#### KNL Mode Reconfiguration, time in seconds [3]

<table>
<thead>
<tr>
<th>Shutdown</th>
<th>Bounce</th>
<th>Fanout Compute</th>
<th>Wait Compute</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>200</td>
<td>110</td>
<td>745</td>
<td>1081</td>
</tr>
<tr>
<td>25</td>
<td>166</td>
<td>109</td>
<td>769</td>
<td>1069</td>
</tr>
<tr>
<td>26</td>
<td>165</td>
<td>108</td>
<td>728</td>
<td>1027</td>
</tr>
</tbody>
</table>

26 177 109 747 1059 Average 17'39"

[1] Includes bounce (hardware initialization, with Aries "linktune") and boot of 3,740 service and compute nodes
[2] *Archive* processing, and *Other* xtbootsys overhead, do not include 487 seconds spent waiting for human input
[3] Includes shutdown, bounce (hardware initialization, excluding Aries) and boot of 3,624 KNL compute nodes
Summary

- KNL configurability brings
  - Choice of modes to use
  - New commands and options for configuring KNLs and monitoring KNL configurations
  - Trade-offs for configuration time vs. execution time
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Q&A

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