Intel® Xeon Phi™ "Knights Landing" (KNL) System Software

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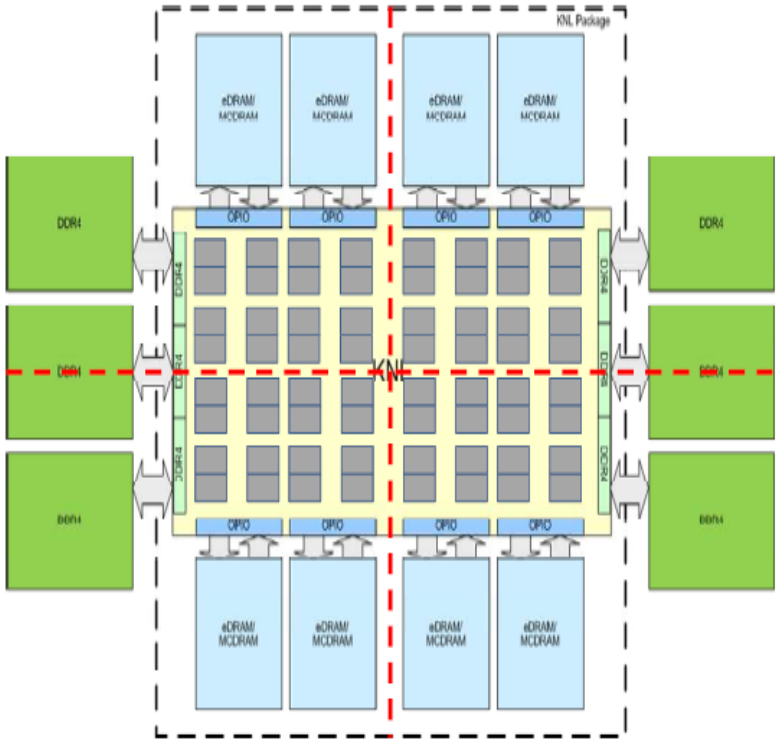
Motivation

- **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

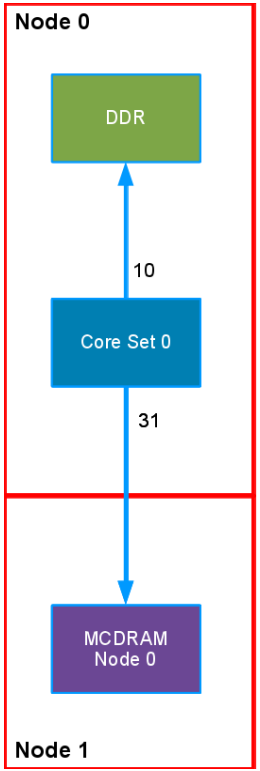
- **As a user, how do I…**
  - Choose the best configuration?
  - Configure the KNLs?
  - Figure out how the KNLs are configured?
  - Use zonesort and what is it?
- **As a system administrator, how do I…**
  - Configure the KNLs?
  - Figure out how the KNLs are configured?
- **Are there costs to reconfiguration?**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

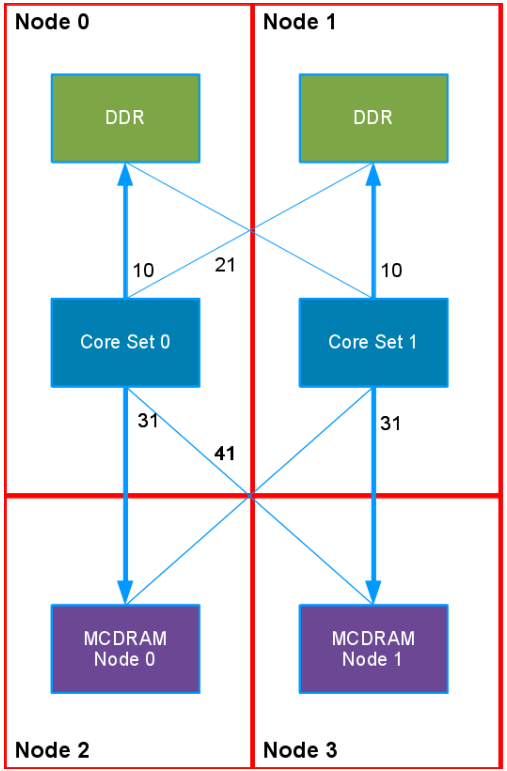
KNL Architecture Overview – a2a, hemi, quad



- **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

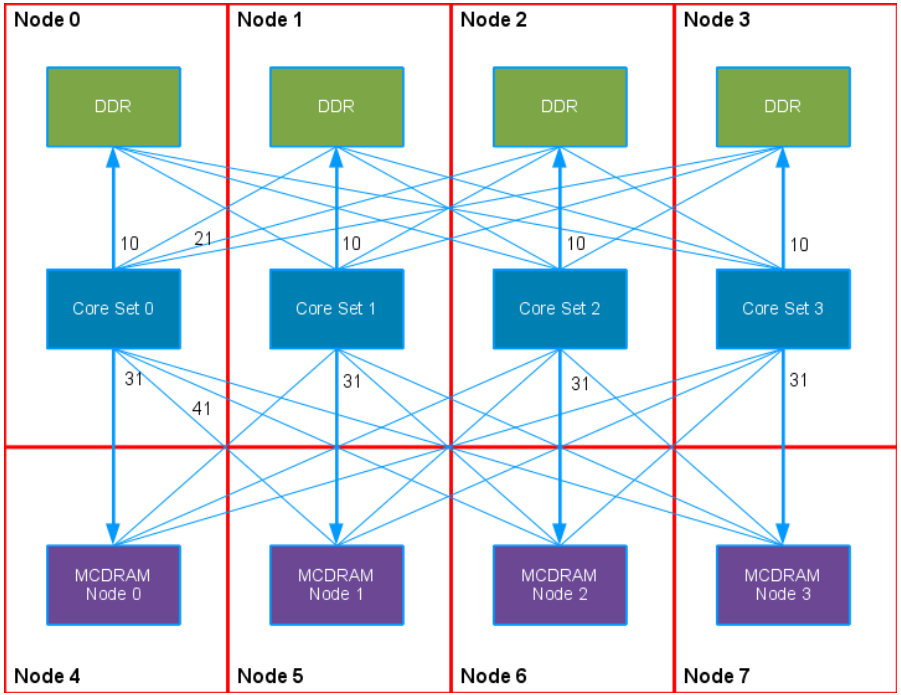
KNL Architecture Overview – snc2



- **NUMA: sub-NUMA cluster 2 (snc2)**
  - Divides DDR and tiles into 2 NUMA nodes
  - Divides flat MCDRAM into 2 NUMA nodes
- **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

SNC4 Tiles per NUMA Node (NN)

KNL SKU	Total Tiles	NN 0 Tiles	NN 1 Tiles	NN 2 Tiles	NN 3 Tiles
7210	32	8	8	8	8
7230	32	8	8	8	8
7250	34	9	9	8	8

- **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

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
$ sinfo -o "%N %b" NODELIST ACTIVE_FEATURES nid00[008-047,052-063,072-115,120-127,140-166]
quad,cache nid00[188-191] cache,quad nid00[167-187] quad,flat
```

- cnselect (from login node)

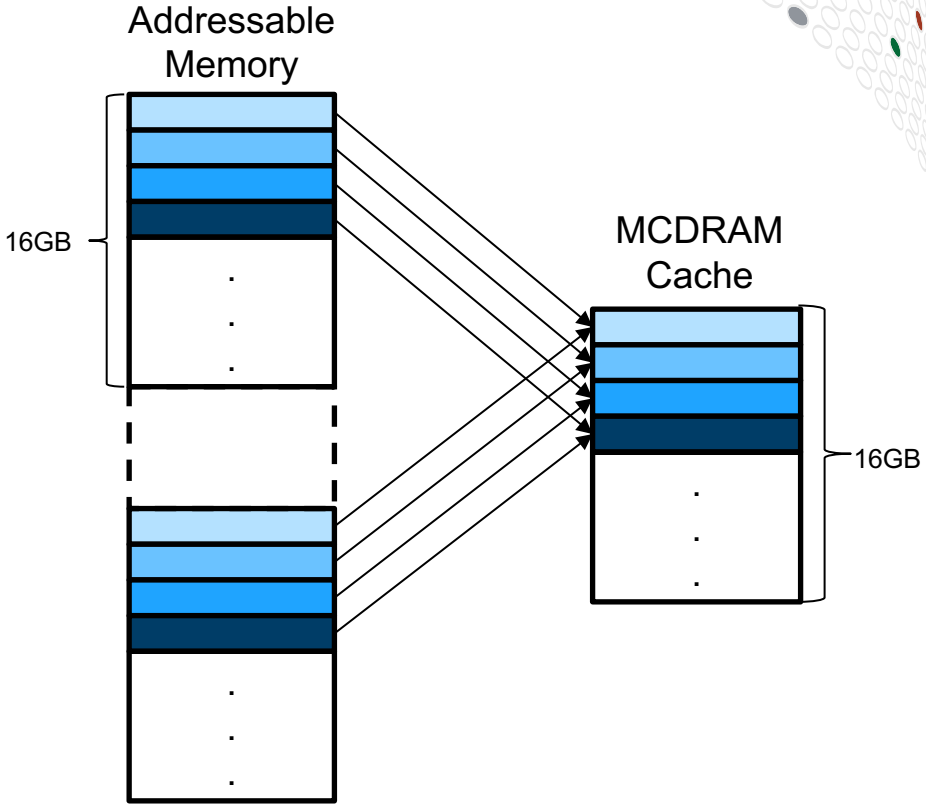
```
$ cnselect hbmcachepct.eq.100.and.numa_cfg.eq.quad
24-27,56-59,68-75,92-94,144-147,160-179
```

- 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

```
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

```
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 c0-0c0s14n0  BUS_STATUS: DDR4 memSpeed          = 0x0960
2016-04-08T07:03:07.486659-05:00 c0-0c0s14n0              MCDRAM Active count   = 0xFF
2016-04-08T07:03:07.486676-05:00 c0-0c0s14n0              MCDRAM speed          = 0x48
2016-04-08T07:03:07.486694-05:00 c0-0c0s14n0              MCDRAM totalMem       = 0x00000100
2016-04-08T07:03:07.486712-05:00 c0-0c0s14n0              MCDRAM totalCache     = 0x00000100
2016-04-08T07:03:07.486731-05:00 c0-0c0s14n0              MCDRAM totalFlat      = 0x00000000
2016-04-08T07:03:07.486748-05:00 c0-0c0s14n0              MCDRAM memoryModel    = 0x04
2016-04-08T07:03:07.486770-05:00 c0-0c0s14n0              MCDRAM memoryMode     = 0x00
2016-04-08T07:03:07.486781-05:00 c0-0c0s14n0              MCDRAM totalClusters  = 0x04
2016-04-08T07:03:07.486793-05:00 c0-0c0s14n0              MCDRAM cacheRatio     = 0x04
```

How was the KNL configured? (BIOS decoder)

MCDRAM memoryModel	capmc NUMA config
0x00	a2a
0x01	snc2
0x02	snc4
0x03	hemi
0x04	quad

MCDRAM memoryMode	MCDRAM cacheRatio	capmc MCDRAM config	cache % of MCDRAM
0x00	0x04	cache/100	100%
0x01	0x00	flat/0	0%
0x02	0x01	split/25	25%
0x02	0x02	equal/50	50%

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

```
<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_mcdram_cfg) request is  authorized
<157>1 2017-04-18T08:28:59.007533-05:00 smw xtremoted_dbutil 55110 - [hss_xtremoted@34]
do_key_value_edit: Setting `mcdram_cfg=cache` for nids
[128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,160,161,16
2,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,56,57,58,59,92,93,94,
95,24,25,26,27,68,69,70,71,72,73,74,75]
```

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]

Archive[2]	*Bounce*	*Boot and SDB*	*Fanout Service*	*Wait Service*	*Fanout Compute*	*Wait Compute*	*Other[2]*	*Total*	
44	738	408	52	346	126	729	65	2508	
								41'48"	

KNL Mode Reconfiguration, time in seconds [3]

Shutdown	*Bounce*	*Fanout Compute*	*Wait Compute*	*Total*	
26	200	110	745	1081	
25	166	109	769	1069	
26	165	108	728	1027	
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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