Portability and Platform-Specific Work

Chapel Team, Cray Inc.
Chapel version 1.13
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Outline

- Chapel on Intel® Xeon Phi™ "Knights Landing" (KNL)
  - Chapel Support for KNL High-Bandwidth Memory (HBM)
- Unification of Cray (CCE) Configuration
- Python 2/3 Compatibility
- Other Portability Work
Chapel on Intel® Xeon Phi™ "Knights Landing" (KNL)
Chapel on KNL: Background

Source: KNL HBM Usage Overview
Chapel on KNL: Background

- Previous releases included Knights Corner (KNC) support

- Targeting KNC with Chapel has several limitations
  - requires a special build of the module
  - only supports Intel as the target compiler
  - all communication has to be bounced through the host processor
    - cannot use "native" communication layers (e.g., ugni/gasnet-aries)
  - limited amount of memory

- KNC was a good starting point for becoming "KNL-ready"
  - allowed us to explore running on a many-core architecture
    - 60+ cores (4 threads per core)
      - each core is relatively slow compared to a traditional Xeon
    - wide (512 bit) vector units
Chapel on KNL: Background

- **Targeting KNL addresses several KNC-specific limitations:**
  - binary-compatible with Xeon Processors
  - support from Intel, GNU, and Cray target compilers
  - can run as a self-hosted processor
  - can support native communication layers
  - substantially higher memory capacity

- **That said, KNL remains a unique many-core architecture**
  - 60+ cores (with 4 threads per core)
  - support for AVX-512 (wide vector units)
  - high-performance on-package memory (MCDRAM)
    - a.k.a. high-bandwidth memory (HBM)
  - several "clustering" modes available
    - all-to-all, quadrant, sub-numa
Chapel on KNL: Background

- **Several KNL-based systems will be coming online soon**
  - e.g., Cori and Trinity: two large systems being manufactured by Cray
    - each system will have over 9,000 self-hosted KNL nodes
    - will be running a new version of Cray's OS and system management stack

- **Main KNL goal for 1.13 was to simply get up and running**
  - intentionally modest, due to limited access to hardware/systems

- **Secondary goal: start looking at performance**
  - improve multi-threaded performance using Qthreads tasking
  - add a locale model that supports targeting HBM
    - ongoing work, reported on in following section
  - start exploring vectorization performance
Chapel on KNL: This Effort

- Default to qthreads tasking on KNC
  - previously defaulted to fifo
    - got poor performance with qthreads in early days of KNC work
  - subsequent work with qthreads has resulted in better performance
    - using different scheduler, affinity options, etc.
  - had to disable guard pages for a few tests
    - concurrent calls to mprotect() appear to be expensive on Xeon Phi
  - stream performance is now on par with reference for KNC
    - early results on KNL also look promising

- Numerous bug fixes for CLE 6.X and KNL
  - primarily related to differences with new Cray OS
    - updates to ugni comm layer memory registration
    - fixes to hwloc for /proc/mounts overflow bug
    - updates to module build process
    - several miscellaneous bug fixes
Chapel on KNL: Impact

- Achieving good multi-threaded performance on KNC
  - and on KNL for the limited testing we’ve had the chance to do

- Correctness test suite passing for all KNL configurations
  - matrix of nightly testing over comm/tasking layers vs. target compilers:

<table>
<thead>
<tr>
<th>Configuration Matrix</th>
<th>cray</th>
<th>intel</th>
<th>gnu</th>
</tr>
</thead>
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<tr>
<td>ugni-qthreads</td>
<td>🟦</td>
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</tr>
</tbody>
</table>

(blue means “clean run” in our test system)
Chapel on KNL: Next Steps

- **Retire Chapel’s support for KNC**
  - was a useful stepping-stone towards KNL
  - we believe it is no longer important to Chapel’s end-users
    - please let us know if we’re mistaken!

- **Add KNL-specific locale model to support targeting HBM**

- **Verify that Qthreads provides good performance on KNL**
  - and see if guard page overhead can be lowered

- **Work on vectorization improvements/optimizations**
  - and explore any potential KNL-specific optimizations
Chapel Support for KNL High-Bandwidth Memory (HBM) (an ongoing effort)
KNL HBM: Background

● KNL supports two memory systems:
  ● off-package DDR memory
    ● 90+ GB/s and up to 384 GB
  ● high-performance on-package memory (a.k.a. MCDRAM or HBM)
    ● 400+ GB/s and up to 16 GB

● MCDRAM can operate in different modes:
  ● partly or entirely as a cache to system memory
  ● allocating all data in the MCDRAM
  ● as a memory that is independent from system memory
    ● programs use it by allocating explicitly from the MCDRAM

● KNL will support dividing into 4 distinct NUMA domains

Sources: Intel KNL Disclosures  KNL HBM Usage Overview
**KNL HBM: Representing Using Locales**

- **Represent MCDRAM as part of a Chapel locale model**
  - our first example of a *memory-only* sub-locale
  - such locales can be used like any other:
    - you can target them using on-statements
      - to store data
      - to execute tasks
    - you can store them in an array and target them with distributions

- **The following slides propose our default policy for KNL**
  - since it’s part of a locale model, none of this is baked into the compiler
    - i.e., if you want a different KNL policy, you can create one
    - (or you can advocate for changes to ours)

- **This is all work-in-progress**
KNL HBM: Proposed Policy

- Tasks on *memory locales* execute on the parent
  - but with a constraint: any allocations are from the designated memory

- Tasks on top-level KNL locales use a default child memory
**Challenge: How to represent distinct NUMA domains?**
- give memory sub-locales to each top-level KNL locale, as before
- also give each KNL locale multiple NUMA sub-locales
- give each NUMA sub-locale its own memory sub-locales
KNL HBM: NUMA Locales

- **Executing on a top-level KNL locale will:**
  - choose among the NUMA sub-locales for where to run the task (as in the NUMA locale model)
  - use a default memory type for its allocations
KNL HBM: NUMA Locales

- **Executing on a KNL locale's memory sub-locale will:**
  - choose among the NUMA sub-locales for where to run the task (as in the previous case)
  - use the specified memory type for its allocations
**KNL HBM: NUMA Locales**

- Executing on a KNL locale's NUMA sub-locale will:
  - run the task on one of the cores within the NUMA domain
  - and limit child tasks to those same cores, unless an on-clause is used
  - use a default memory type for its allocations

![Diagram](image)
**KNL HBM: NUMA Locales**

- Executing on a NUMA domain's memory sub-locale will:
  - run the task on one of the cores within the NUMA domain
  - and limit child tasks to those same cores, unless an on-clause is used
  - use the specified memory type for allocations
Memory locales are locales like any other
Yet, we don't want forall loops to run tasks on memory sub-locales

Default foralls currently use simple locale model methods:

```
proc getChildCount(): int
proc getChild(idx:int): locale
```

We’ll need to update this interface to avoid the memories
**KNL HBM: Allocation Experiments**

- Developed prototype KNL locale model
  - targeted *hbw_malloc* functions provided by *memkind* library

- Demonstrated allocating explicitly as follows:

  ```c
  // get HBM with a temporary interface: LocaleModel.hbm
  var hbm = (here:LocaleModel).hbm;

  on hbm {
    // demonstrated this array is allocated with *hbw_malloc*
    var A: [1..1000] int;
    A = 1;
  }
  ```

- In-progress: Support for Block distribution over HBM
Impact:
- Well on our way to MCDRAM support for KNL
  - Chapel programs will be able to explicitly program the memory
  - Arrays will be able to be distributed over many MCDRAMs in a system

Status:
- early prototype demonstrated (not included in v1.13)

Next Steps:
- evolve Locale interface to support HBM
- support capability-oriented interfaces for users for portability, e.g.:
  - “get locale ancestor running the operating system”
  - “get a fast-memory sub-locale”
- complete implementation of KNL Locale Model
- investigate NUMA support on KNL
- investigate performance
Unification of Cray (CCE) Configuration
CCE Target Compiler: Background

- On Crays we support Cray, GNU, and Intel target compilers

- Cray (CCE) hasn’t supported all runtime configurations
  - used fifo tasking  couldn’t build qthreads or muxed (inline ASM)
  - used gasnet comm  couldn’t build ugni (missing atomics)
  - used dlmalloc memory  couldn’t build tcmalloc (C++, compiler flags, etc)
  - lacked regexp support  couldn’t build re2 (Makefiles used GNU flags)

- As a result, using the CCE back-end limited performance
  - and did not support regular expressions

- CCE 8.4.0 allows us to improve on this by adding…
  - inline ASM support
  - additional GNU compatibility
  - missing atomics
CCE Target Compiler: This Effort

- **Build qthreads+hwloc with CCE**
  - required working around broken ffs() for hwloc
  - required CCE 8.4.0 for Qthreads (inline ASM)

- **Build muxed with CCE**
  - required CCE 8.4.0 (inline ASM)

- **Build jemalloc with CCE**
  - required building with –hipa2 to work around inlining bug
  - had to avoid throwing GNU-specific flags

- **Build ugni with CCE**
  - required building with –hipa0 to work around inlining bug
  - required jemalloc, since getting tcmalloc to build proved impractical

- **Build re2 with CCE**
  - edited Makefiles to avoid GNU-specific flags
CCE Target Compiler: Impact

- CCE back-end now supports the full runtime
  - significantly better performance due to qthreads+hwloc, jemalloc, ugni
  - regular expression support

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CCE back-end now supports the full runtime

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---

CCE back-end now supports the full runtime

- significantly better performance due to qthreads+hwloc, jemalloc, ugni
- regular expression support
Python 2/3 Compatibility
Python 2/3 Compatibility: Background

Background:
- Building Chapel required Python 2.x, but Python 3 is used widely
- Had become our most frequent barrier to successful end-user installs

This Effort:
- Modified Chapel configuration scripts to support Python 3.x as well

Impact:
- Users can now build Chapel with Python 2 or 3

Status:
- Nightly testing checks compatibility with Python 2.6, 2.7, and 3.5

Next Steps:
- Make the testing infrastructure Python 3-compatible
  - e.g., start_test
Other Portability Work
Other Portability Work

- Switched PGI C++ compiler from pgCC to pgc++
- Worked around code base incompatibilities with gcc 5.1
  - seemingly a gcc 5.1 compiler bug, as unlikely as that seems…
- Fixed portability issues to newer Cygwin installs
- Removed stale Xcode support
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