Runtime and Third-Party Improvements

Chapel Team, Cray Inc.

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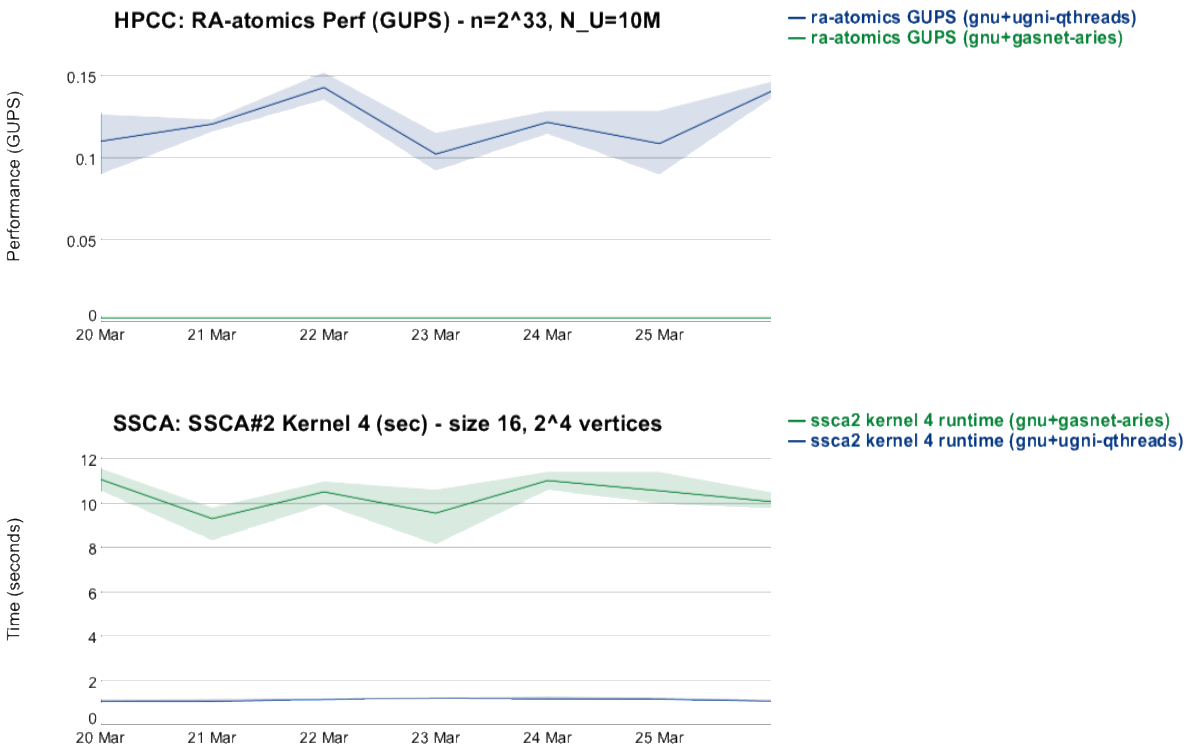
Ugni/Muxed Background

Ugni/Muxed: Introduction

- **Chapel supports Cray-specific comm and tasking layers**
  - CHPL_COMM=ugni
    - interacts with NIC via lightweight uGNI (user Generic Network Interface)
    - provides access to network atomics (CHPL_NETWORK_ATOMICS=ugni)
    - supports a high degree of communication concurrency
  - CHPL_TASKS=muxed
    - implements task-switching in user-space
- **Tuned for fine-grain, latency-bound codes like SSCA/RA**
- **Historically, only available when using pre-built module**
  - closed-source/proprietary for IP reasons
    - patent for IP was granted last year

Ugni: Background

- **Ugni offers significant performance advantages**
  - outperforms gasnet-aries in all studied applications
    - usually significantly, particularly for codes it was originally tuned for



Muxed: Background

- **Muxed used to offer significant performance advantages**
  - user-space task-switching allowed it to vastly outperform fifo
- **Nowadays qthreads typically outperforms muxed**
  - qthreads (our default) is highly optimized
    - also does user-space task switching
  - designed as a general tasking solution
    - whereas muxed was specifically designed/tuned for SSCA
  - qthreads is also numa-aware and has built-in full/empty support
- **Few notable cases where muxed still performed better**
  - as of 1.14: FFT, HPL, and MiniMD

Ugni/Muxed: Background

- **Have wanted to open-source ugni**
  - users building from source will receive performance benefits
- **Have also wanted to retire muxed**
  - qthreads generally performs much better
  - need to improve qthreads for a few benchmarks before retiring muxed
- **Combined, these efforts will simplify development**
  - eliminate development/maintenance cost for muxed
  - ugni development will use public repo, public issue tracker, etc.

Communication Improvements

Open Source Ugni

Open Source Ugni: This Effort and Impact

This Effort: Open-sourced ugni communication layer

- now included in public repository
- ugni is now our default on Cray machines
  - historically, it was only the default with the pre-built module
- also compiles with PGI now
  - mostly for uniformity and ease of documentation

Impact: Easier development, perf benefit for open-source users

- have already seen benefits of ugni being open-sourced
  - open-source developer was able to test ugni-specific bug-fix
  - opened several GitHub issues to track ugni improvements
- additionally, publicizing ugni motivated us to revisit/review the code
  - led to removal of a performance-limiting memory registration limit

Ugni Registration Limit

Ugni Registration Limit: Background

- **Ugni registers the heap with multiple comm domains**
  - access to individual comm domains is serialized
  - having multiple comm domains improves comm concurrency
    - dramatically improves performance of latency-bound codes (SSCA, RA)
  - ideally, want at least one comm domain per core

- **Early "native" slurm couldn't get exclusive access to NIC**
  - this limited the total amount of memory that could be registered
    - total memory is heapSize * numCommDomains

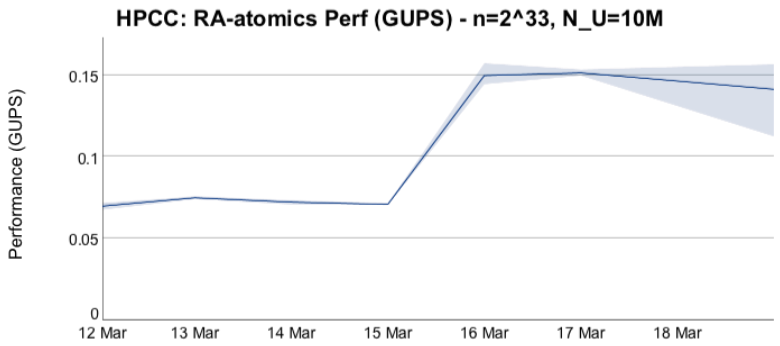
- **Slurm limitation constrained number of comm domains**
  - in practice, could only register up to 15 comm domains
    - ~1/2 the number cores on a modern Xeon-based XC

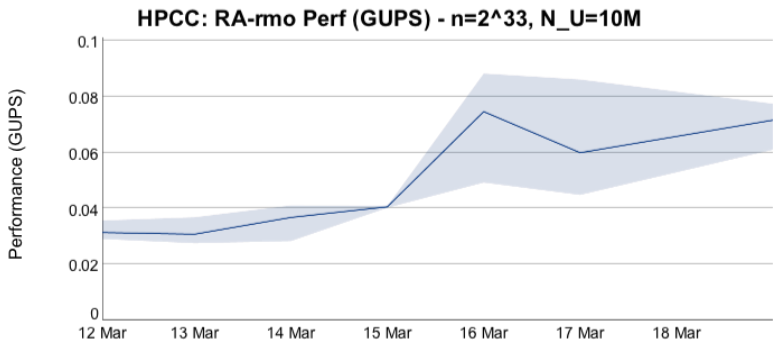
Ugni Registration Limit: This Effort

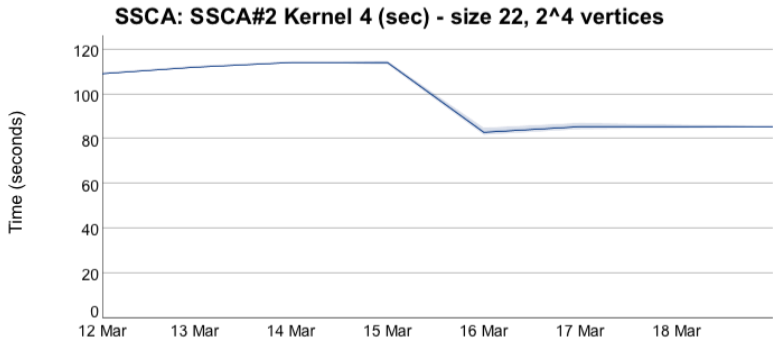
- **Revisited the need for registration limit**
  - learned that slurm can now get exclusive access to the NIC
    - i.e. registration limitation no longer exists
- **Removed comm-domain-limiting code from ugni**
  - limit now uniform between slurm and pbs/aprun systems
- **Comm domain limit is based on the number of cores**
  - currently capped at max of 30 comm domains
    - based on gemini limit; aries supports up to 127
    - doesn't hurt us on current Xeon-based systems
      (but need to revisit for Xeon-Phi and future Xeon systems)

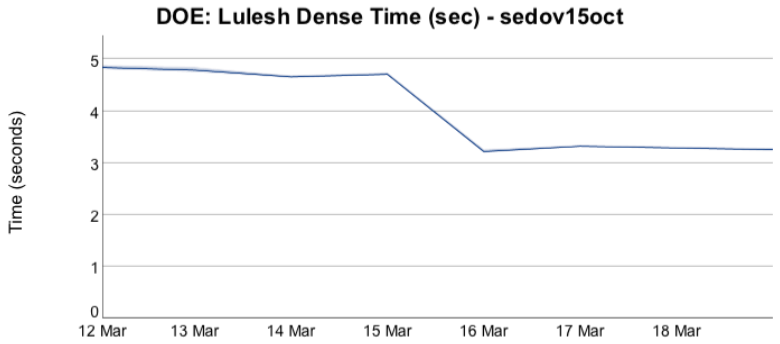
Ugni Registration Limit: Impact

- **Resulted in significant performance improvements**
  - for latency-bound applications run on slurm-managed machines









Ugni Registration Limit: Impact and Next Steps

Impact:

- led to some significant performance improvements

Next Steps:

- continue to improve ugni performance
  - evaluate performance of increasing comm domain limit for aries
- investigate poor gasnet-aries performance
  - evaluate GASNet's --enable-gni-multi-domain support

Tasking Improvements

Register Qthreads Task Stacks

Registered Task Stacks: Background

- **On Crays, only registered memory can be communicated**
  - unregistered memory has to be copied into a registered segment first
  - for best performance, ugni registers the entire Chapel heap
    - memory in the heap can be directly communicated (no copying needed)
- **Muxed tasking uses Chapel's allocator**
  - means task-stacks are part of the registered heap
- **Historically, qthreads used the system allocator**
  - task-stacks were not part of the registered heap (had to be copied)
- **Extra copying to/from qthreads stacks hurt performance**
  - identified as reason muxed was beating qthreads for FFT and HPL

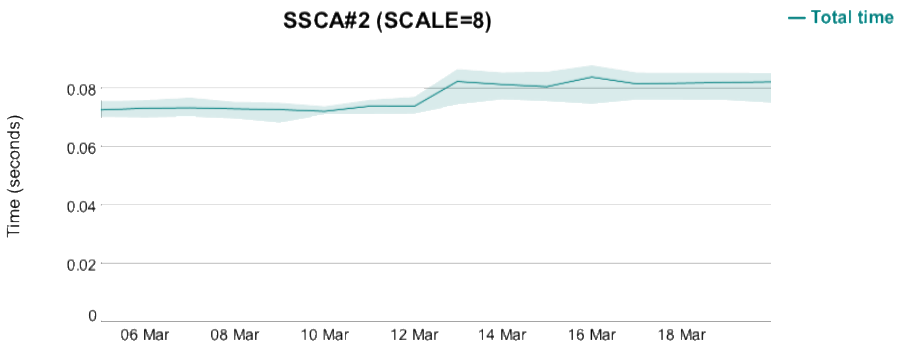
Registered Task Stacks: This Effort

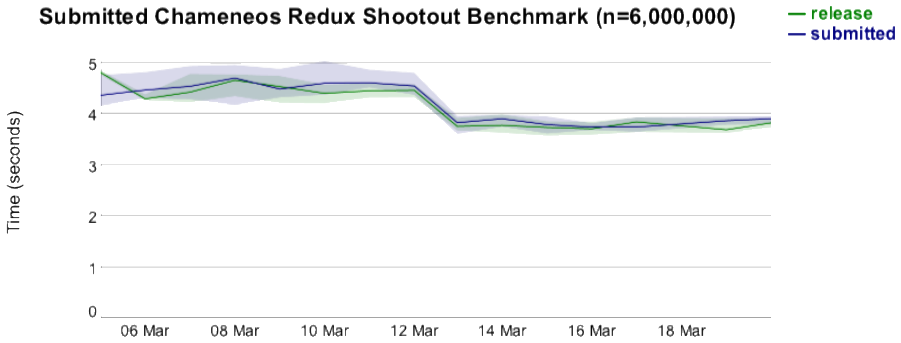
- **Make qthreads use Chapel's allocator**
  - task stacks are now in registered heap (as is all qthreads memory)

- **Worked with qthreads team to add *external allocators***
  - qthreads now has shim layers for qt_malloc, qt_free, etc.
    - default forwards to system allocator (old behavior)
    - new one forwards to Chapel's allocator
  - included in qthreads 1.12 release

Registered Task Stacks: Impact

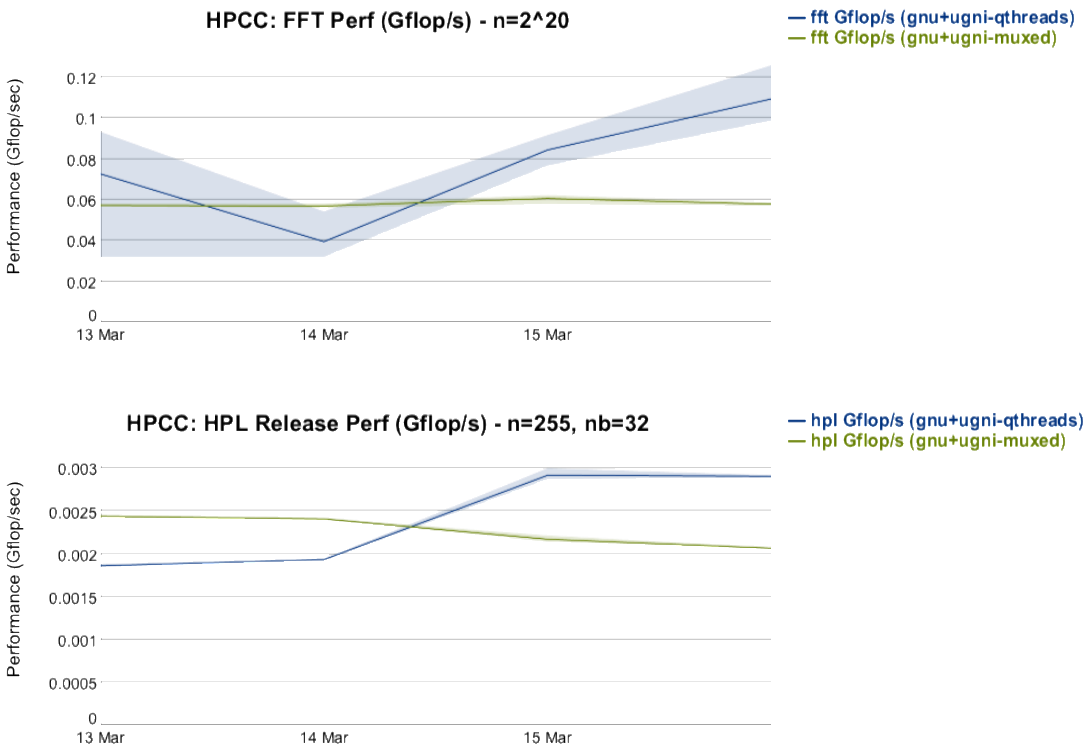
- **No real single-locale performance changes**
  - minor changes (both positive and negative)
    - really just “noise” caused by memory layout differences between allocators





Registered Task Stacks: Impact

- **Improved multi-locale performance**
  - qthreads now outperforms muxed for FFT and HPL



Limit Qthreads Memory Pool

Limit Qthreads Memory Pool: Background

Background: Qthreads aggressively pools memory

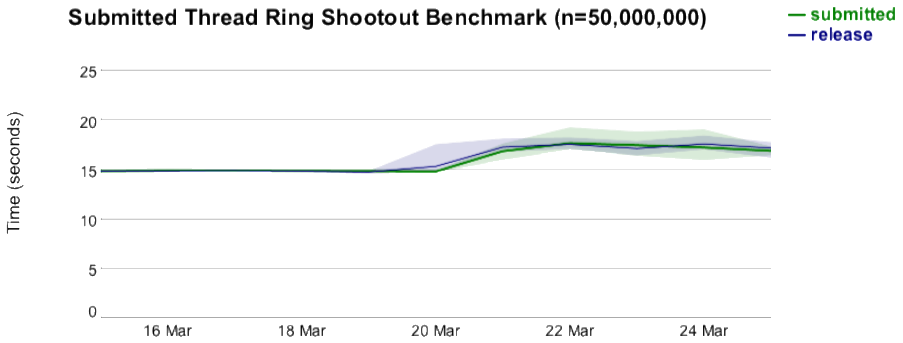
- by default, qthreads allocates space for ~128 items per pool
  - qthreads assumes ~4KB stack size, but our default is 8MB
- Chapel sets limit on qthreads max pool size
  - previously something like: (2 * numCores * stackSize)
  - based on belief that there was a single pool for task stacks
- discovered that there is actually a pool per worker (core)
  - on 68-core KNL, resulted in trying to allocate >30 GB in task-stacks
  - only noticed once qthreads started using our allocator (limited heap size for some apps led to OOM)

This Effort: Further limit qthread pool size

- now just a multiple of the stack size
  - effectively just an upper bound of 65MB (8 default-sized stacks)
  - note that this only affects compute nodes with more than 4 cores

Qthreads Memory Pool Limit: Impact

- **Applications now use less memory**
  - resolved KNL OOMs
- **Minor thread-ring regression for high core-count nodes**
  - thread-ring creates over 500 concurrent tasks
    - new pool limit results in creating more pools



Deprecate Muxed

Deprecate Muxed

Background: No remaining cases where muxed beats qthreads

- array-views work resolved MiniMD difference
- registered task stacks resolved FFT and HPL differences
- task-spawning optimizations further improved qthreads performance

This Effort: Deprecated muxed tasking

- officially deprecated for 1.15 release

Next Steps: Remove muxed source code and documentation

- support will be removed for the 1.16 release

Other Runtime Improvements

Other Runtime Improvements

- **Fixed dynamic linking for gasnet-aries on Cray systems**
- **Fixed support for gasnet+muxed without hugepages**
- **Switched qthreads initializer to run in detached state**
  - contributed by Rob Upcraft
- **Fixed massivethreads for stack-allocated arg-bundles**
  - contributed by Kenjiro Taura

Other Third-Party Improvements

Other Third-Party Improvements

- **Upgraded jemalloc to version 4.5.0**
  - no major performance impact
  - now using a vanilla jemalloc (all our patches accepted upstream)
- **Upgraded Qthreads to version 1.12**
  - added support for external-allocators
  - fixed sleep-interception bug
  - added hybrid spin/condwait for nemesis
- **Upgraded hwloc to version 1.11.6**
  - fixed bug that KNL work encountered
  - improved startup time on high core-count machines by ~25%
- **Upgraded GASNet to version 1.28.0**
- **Made GASNet build amudprun launcher for host machine**

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